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THREE-DIMENSIONAL FINITE-ELEMENT COMPUTER PROGRAM -
USER'S GUIDE

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

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AUGUST 1974

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THREE-DIMENSIONAL FINITE-ELEMENT COMPUTER
PROGRAM—USER'S GUIDE

J. R. Dana* and R. M. Barker**

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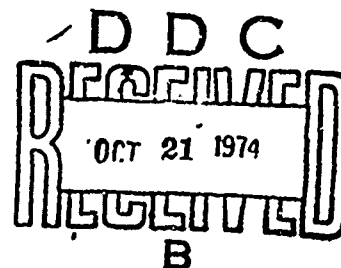
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*Department of Aeronautical Engineering
California Polytechnic State University
San Luis Obispo, California 93407

**Department of Civil Engineering
Virginia Polytechnic Institute & State University
Blacksburg, Virginia 24061



ABSTRACT

The FORTRAN Listing and User's Guide for a Three-Dimensional Linear Thermal-Elastic Finite-Element Computer Program is presented. The program will determine three-dimensional displacement and stress distributions for laminated orthotropic composite materials.

A curved isoparametric element with 24 nodal points and 72 degrees-of-freedom is used to model the individual layers of a laminate. The nodal displacements are determined by minimizing the total potential energy of the system, at the element level, with a conjugate gradient iterative method.

The program is presently (1974) running on an IBM 370/158 computer at Virginia Polytechnic Institute and State University.

NOMENCLATURE

E	Total potential energy
E_{11}	Modulus of elasticity parallel to the fibers
E_{22}	Modulus of elasticity transverse to the fibers
G_{12}, G_{13}, G_{23}	Shear modulus
m, n	$\cos \theta, \sin \theta$ respectively where θ is the angle between lamina and global axes
N	Number of global degrees of freedom
u, v, w	Displacements of a point in x, y, z directions
x, y, z	Global Cartesian coordinates
α	Magnitude of the correction vector
β	$\left \{r_{i+1}\} \right ^2 / \left \{r_i\} \right ^2$
θ	Fiber orientation angle
θ, r, z	Cylindrical coordinates for the global axes
λ_i	Eigenvalues
ξ, η, ζ	Local curvilinear coordinates
a_{ij}	Direction cosines for angle between lamina and global axes
C_{ijkl}	Stiffness constitutive relation for an anisotropic material in the local coordinate system
C'_{ijkl}	Stiffness constitutive relation for an anisotropic material in the global coordinate system
ϵ_{ij}	Strains in constitutive relations for an anisotropic material
ν_{ij}	Poisson's ratio relating normal strain in j -direction due to uniaxial normal stress in i -direction
$\{b\}$	Force vector
$[D]$	Elasticity matrix
$[D]$	A diagonal matrix

$[K]$	Global stiffness matrix
$\{N\}$	Shape functions
$[P]$	An orthogonal matrix
$\{p\}$	Direction of correction vector
$\{r\}$	Residue vector
$[T]$	Coordinate transformation matrix
$\{x\}$	Solution vector (displacements)
$\{x^*\}$	True solution vector (displacements)
$\{\epsilon\}$	Error vector, $\{\epsilon\} = \{x^*\} - \{x\}$
$\{\xi\}$	Change of variable vector, $\{\xi\} = [P]^T \{\epsilon\}$

Subscripts:

1, 2, 3	Local system
x, y, z	Global system

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
ANALYSIS	3
A. Three-Dimensional Isoparametric Lamina Element	3
B. Conjugate Gradient Equation Solver	9
DESCRIPTION OF INPUT-OUTPUT DATA	15
A. Input Data for Step 2	15
B. Card Input for Step 3	19
C. Card Input for Step 4	21
D. Printed Output from Step 2	21
E. Printed Output from Step 3	22
F. Printed Output from Step 4	22
ACKNOWLEDGMENTS	23
REFERENCES	24
APPENDIX A -- Program Listing Steps 2, 3, & 4	
APPENDIX B -- Input/Output Units and Sample JCL	
APPENDIX C -- Rectangular Plate Mesh Generator	
APPENDIX D -- Hole in Rectangular Plate Mesh Generator	

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Three-Dimensional Isoparametric Lamina Element	4
2. Fiber Orientation Within Lamina Element	8
3. Two-Dimensional Representation of the Conjugate Gradient Procedure	12
C-1 Mesh for Rectangular Plate	C-2
D-1 Mesh for Rectangular Plate with a Hole	D-2

INTRODUCTION

The purpose of this computer program is to perform static, linear, thermal-elastic analyses of three-dimensional laminated composites. The basis for the analysis is a curved three-dimensional, isoparametric, 72 degree-of-freedom element with cubic interpolation functions in plan and a linear interpolation function through-the-thickness. This element can be used to model each layer of a laminated composite.

The primary deviation from the normal finite-element displacement formulation is that the global stiffness matrix is not formed. In this formulation only the unique element stiffness matrices are calculated. The nodal displacements are then determined by minimizing the total potential energy of the system at the element level with a conjugate gradient iterative method. The technique of not forming the global stiffness matrix greatly reduces the storage requirements if the number of unique elements is small. For example, problems of over 3000 degrees-of-freedom have been solved in core with less than 35,000 double precision words, including arrays and code. When the number of unique elements is greater than four, a direct access data file is used which increases the run time by about 60 percent.

The three nodal displacements (x , y and z) at each node obtained from the minimization technique are used in conjunction with the interpolation (shape) function to give the six stress components at each node. The stresses are calculated at the nodal points for each element.

The program and input data description that follow are intended to be used as a reference for a person with some knowledge of this

program. It is not written with sufficient detail to teach a person to use the program.

ANALYSIS

A. Three-Dimensional Isoparametric Lamina Element

The isoparametric element (Figure 1) used in this program was coded by Lin (7), and is similar to an element described by Ahmad, et al., (1) which was used to solve isotropic shell and plate problems. The development of the element stiffness matrix follows what has now become a standard procedure where the elastic properties related to the reference axes and the derivatives of the shape function related to the same axes through the Jacobian are used to form the strain energy density. The strain energy density is then numerically integrated (Gauss 4 x 4 x 2 rule) over the volume of the element to form the element stiffness matrix. Details of determining the necessary derivatives and forming the Jacobian matrix are given in the text by Zienkiewicz (10).

1. Interpolation function (shape function)

The triside nodes, top and bottom surfaces, are described by cubic interpolation functions while sections across the thickness are generated by straight lines. The relationship between the Cartesian coordinates (x, y and z) and the local normalized curvilinear coordinates (ξ , η , ζ) is given by

$$\begin{aligned}x &= N_1 x_1 + N_2 x_2 + \dots + N_{24} x_{24} = \{N_i\}^T \{x_i\} \\y &= N_1 y_1 + N_2 y_2 + \dots + N_{24} y_{24} = \{N_i\}^T \{y_i\}\end{aligned}\quad (1)$$

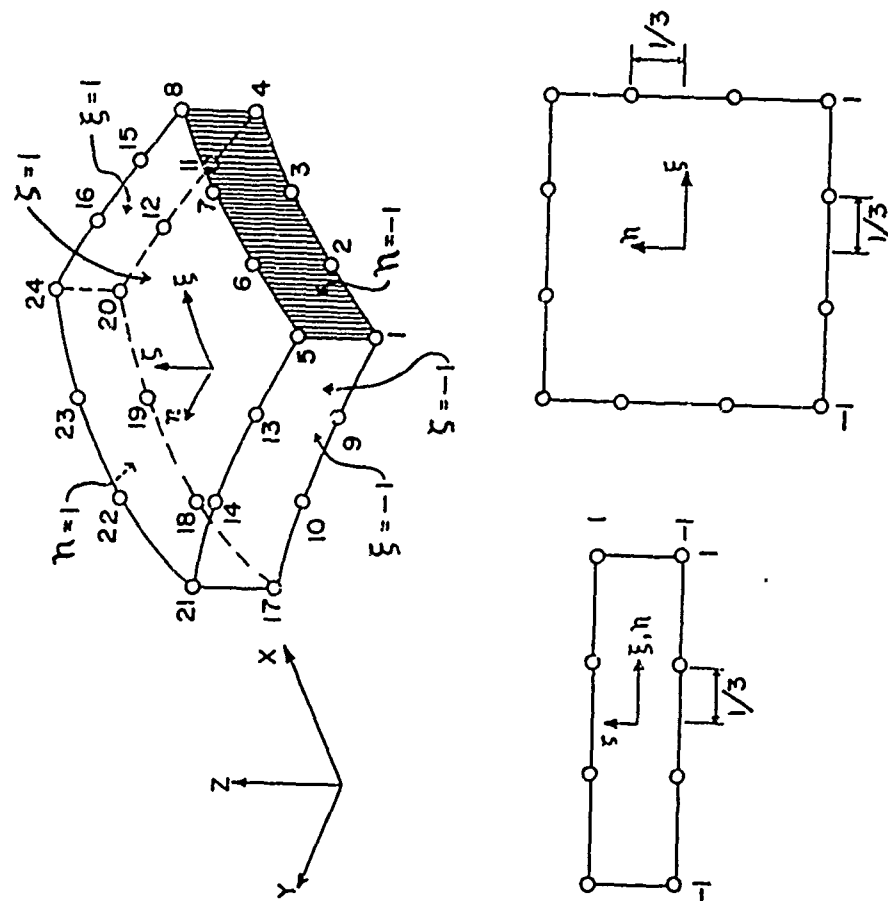


FIGURE 1: Three-Dimensional Isoparametric Lamina Element

$$z = N_1 z_1 + N_2 z_2 + \dots + N_{24} z_{24} = \{N_i\}^T \{z_i\}$$

where N_i are the isoparametric interpolation functions for the 24 nodal points. Introducing the notation

$$\xi_0 = \xi \xi_i, \quad \eta_0 = \eta \eta_i, \quad \zeta_0 = \zeta \zeta_i \quad (2)$$

the form for the interpolation functions becomes for the corner nodes with $\zeta_i = \pm 1$, $\eta_i = \pm 1$, and $\xi_i = \pm 1$

$$N_1 = \frac{1}{64} (1+\xi_0)(1+\eta_0)(1+\zeta_0) [9(\xi^2 + \eta^2) - 10]. \quad (3)$$

For nodes along the sides $\xi_i = \pm 1$ with $\eta_i = \pm \frac{1}{3}$, $\zeta_i = \pm 1$

$$N_i = \frac{9}{64} (1+\xi_0)(1+9\eta_0)(1+\zeta_0)(1-\eta^2). \quad (4)$$

For nodes along the sides $\eta_i = \pm 1$ with $\xi_i = \pm \frac{1}{3}$, $\zeta_i = \pm 1$

$$N_i = \frac{9}{64} (1+9\xi_0)(1+\eta_0)(1+\zeta_0)(1-\xi^2). \quad (5)$$

The same functions are used to describe the displacement pattern (u, v, w) over the element in terms of the displacements (u_i, v_i, w_i) at the nodes, i.e.,

$$\begin{aligned} u &= \{N_i\}^T \{u_i\} \\ v &= \{N_i\}^T \{v_i\} \\ w &= \{N_i\}^T \{w_i\} \end{aligned} \quad (6)$$

2. Constitutive relation (material properties)

The constitutive relations used for the element are based on each lamina of the composite which is assumed to behave as an orthogonal anisotropic material. Therefore, the 21 elastic constants for a general anisotropic material are reduced to nine independent elastic constants which are given below, in matrix form, for the principal axes of elastic symmetry (1,2,3).

$$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{12} \\ \tau_{13} \\ \tau_{23} \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} & D_{13} & 0 & 0 & 0 \\ & D_{22} & D_{23} & 0 & 0 & 0 \\ & & D_{33} & 0 & 0 & 0 \\ & & & D_{44} & 0 & 0 \\ \text{Symmetry} & & & & D_{55} & 0 \\ & & & & & D_{66} \end{bmatrix} \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{23} \end{bmatrix} \quad (7)$$

where

$$D_{11} = \frac{1-\nu_{23}\nu_{32}}{F} E_{11}, \quad D_{22} = \frac{1-\nu_{13}\nu_{31}}{F} E_{22}, \quad D_{33} = \frac{1-\nu_{12}\nu_{21}}{F} E_{33},$$

$$D_{12} = \frac{\nu_{12} + \nu_{13}\nu_{32}}{F} E_{22}, \quad D_{13} = \frac{\nu_{13} + \nu_{12}\nu_{23}}{F} E_{33}, \quad D_{44} = G_{12},$$

$$D_{23} = \frac{\nu_{23} + \nu_{21}\nu_{13}}{F} E_{33}, \quad D_{55} = G_{13}, \quad D_{66} = G_{23}$$

and

$$F = 1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32} - \nu_{12}\nu_{23}\nu_{31} - \nu_{21}\nu_{13}\nu_{32} -$$

For an arbitrary orientation of the lamina, as shown in Figure 2, the principal axes (1,2,3) will not coincide with the reference axes (x, y, z) of the laminate; therefore, a rotational transformation must be performed. In general, the transformation takes the following tensor form:

$$C'_{ijkl} = a_{ir} a_{js} a_{kt} a_{lu} C_{rstu} \quad (8)$$

where

C'_{ijkl} and C_{rstu} are the components of a fourth order Cartesian tensor relating stresses and strains. The prime and unprimed components represent the reference axes and the principal axes, respectively, and

a_{mn} is a second order Cartesian tensor of direction cosines for a rotation about the z-axis.

Since C'_{ijkl} and C_{rstu} have 81 elements each and would be represented by fourth order arrays in FORTRAN, it is more convenient to perform the transformation in matrix form as shown below.

$$[D_x] = [T]^T [D_1] [T] \quad (9)$$

where

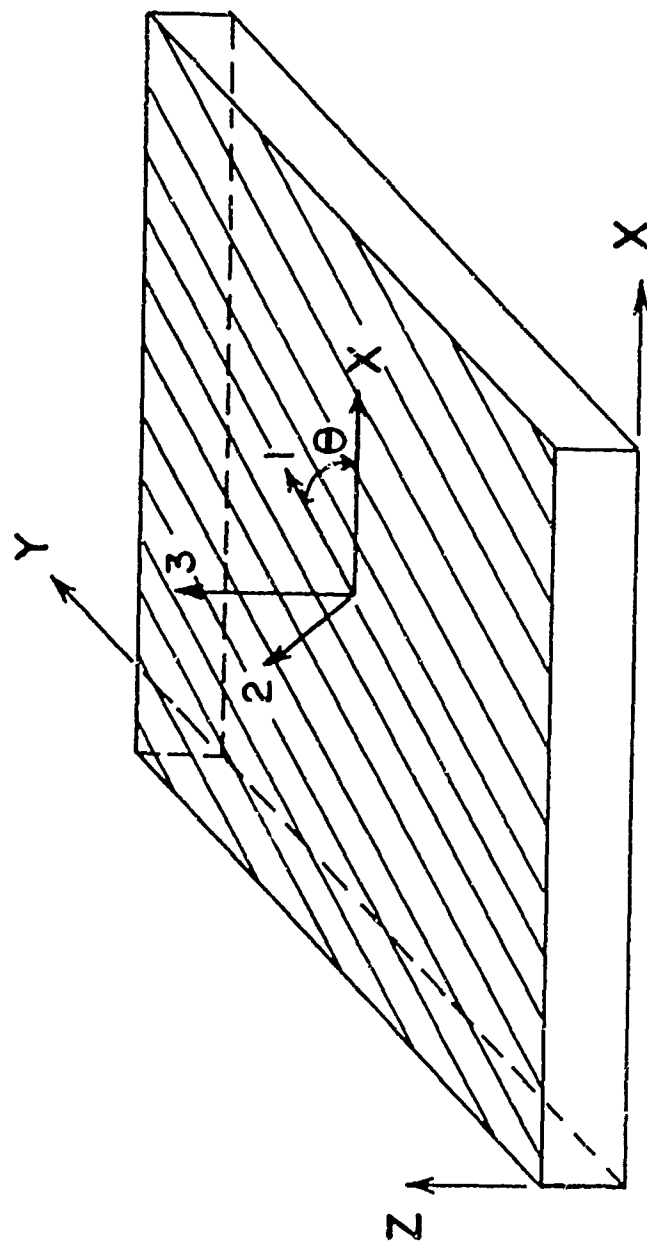


FIGURE 2: Fiber Orientation Within Lamina Element

$$[T] = \begin{bmatrix} m^2 & n^2 & 0 & -2mn & 0 & 0 \\ n^2 & m^2 & 0 & 2mn & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ mn & -mn & 0 & m^2 - n^2 & 0 & 0 \\ 0 & 0 & 0 & 0 & m & -n \\ 0 & 0 & 0 & 0 & n & m \end{bmatrix} \quad (10)$$

and

$[D_x]$ and $[D_1]$ are the elastic matrices for the reference axes and principal axes, respectively.

Using references (2) and (8), it can be shown that the tensor transformation and the matrix transformation are equivalent for orthotropic materials. It should be noted that $[T]$ and $[D]$ are not Cartesian tensors; therefore, $[T]^{-1} \neq [T]^T$.

B. Conjugate Gradient Equation Solver

1. Description of the method

The equation solver used in this program is an adaptation of the conjugate gradient (CG) method originally presented by Hestenes and Stiefel (6) for linear systems in 1952. In more recent papers Fried (5) and Fox and Stanton (4) make direct reference to finite-element applications and indicate that the minimization process of the CG technique is equivalent to minimizing the total potential energy of the system. The method is an iterative process that will, apart from roundoff errors, converge to the exact solution in no more than

N iterations, where N is the order of the matrix.

The rate of convergence of the CG method is dependent on the eigenvalues of the global stiffness matrix (9); therefore, it is problem dependent, making it difficult to make a general comparison with other techniques. The dependence on the eigenvalues can be shown by considering the energy E which is to be minimized as

$$E = \frac{1}{2}\{x\}^T [K]\{x\} - \{x\}^T \{b\} \quad (11)$$

where [K] is the global stiffness matrix, {b} is the force vector, and {x} is the displacement vector which is to be selected to minimize the total potential energy. The energy E will be a minimum at the point

$$\{x\} = \{x^*\} \quad (12)$$

when

$$\frac{\partial E}{\partial x} = [K]\{x^*\} - \{b\} = 0. \quad (13)$$

At a particular step in the iteration process

$$\{x\} = \{x^*\} + \{\epsilon\} \quad (14)$$

where the vector {ε} is the error in {x}. Putting equation (14) into equation (11) yields

$$E = \frac{1}{2}(\{x^*\} + \{\epsilon\})^T [K](\{x^*\} + \{\epsilon\}) - (\{x^*\} + \{\epsilon\})^T \{b\} \quad (15)$$

which after some manipulation and use of equation (13) becomes

$$E = \frac{1}{2}\{\epsilon\}^T [K] \{\epsilon\} - \frac{1}{2}\{x^*\}^T \{b\}. \quad (16)$$

This can also be written as

$$E + \frac{1}{2}\{x^*\}^T \{b\} = \frac{1}{2}\{\epsilon\}^T [K] \{\epsilon\} = \frac{1}{2}k_{ij}\epsilon_i\epsilon_j = S \quad (17)$$

where S is a hyperellipsoidal surface in variable $\{\epsilon\}$, with center at $\{\epsilon\}$ equal $\{0\}$. Since $[K]$ is symmetric, there exists an orthogonal matrix $[P]$ such that

$$[P]^T [K] [P] = [D] \quad (18)$$

where $[D]$ is a diagonal matrix containing the eigenvalues λ_i of $[K]$. Using the change of variable,

$$\{\xi\} = [P]^T \{\epsilon\}. \quad (19)$$

Equation (17) can be written as

$$S = \frac{1}{2}\{\epsilon\}^T [K] \{\epsilon\} = \frac{1}{2}\{\xi\}^T [D] \{\xi\} = \frac{1}{2}\lambda_i \xi_i^2. \quad (20)$$

The surface S described by equation (20) is shown for the two-dimensional case in Figure 3. The major and minor axes of the ellipse are proportional to the inverse of the square root of the eigenvalues of $[K]$. The vector $\{p\}$ is normal to the surface of the ellipse and indicates the direction in which $\{x\}$ will be corrected. It can be seen that, if λ_1 and λ_2 are similar in magnitude, the ellipse approaches a circle and $\{p\}$ will be directed toward the

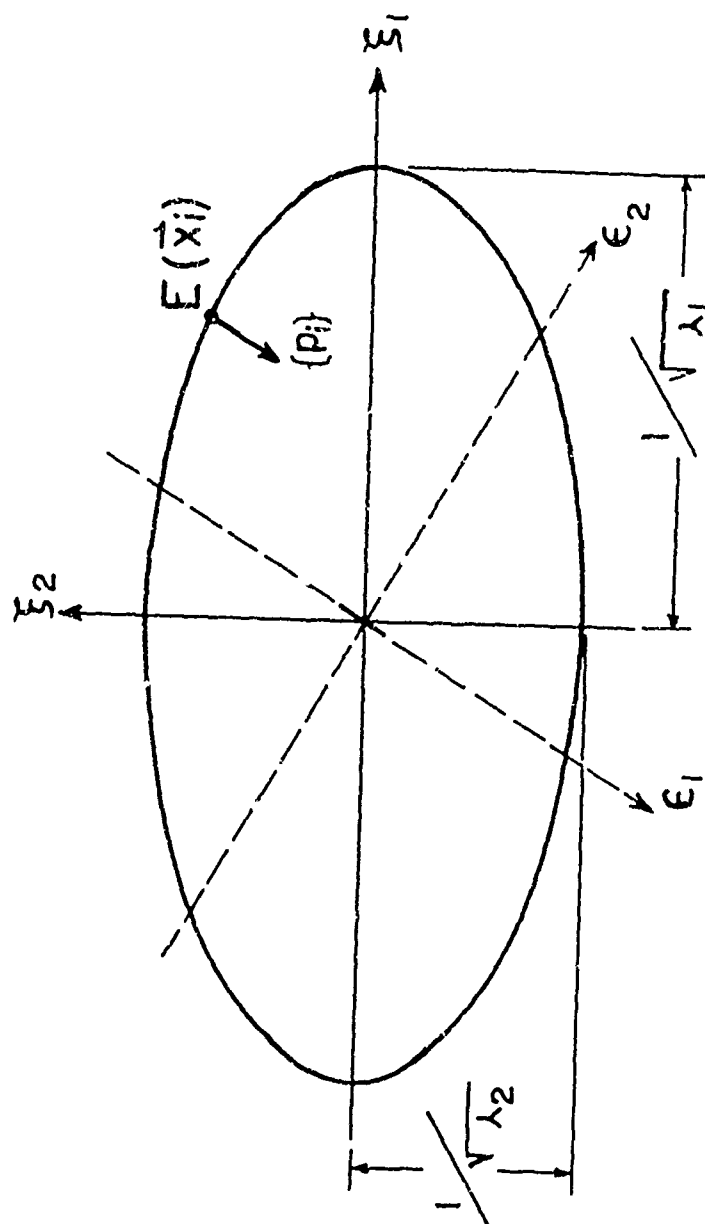


FIGURE 3: Two-Dimensional Representation of the Conjugate Gradient procedure.

origin where ϵ_1 and ϵ_2 are zero. However, if the magnitudes of λ_1 and λ_2 are quite different, then $\{p\}$ will not be in the direction of the origin and convergence to ϵ_1 and ϵ_2 in the neighborhood of zero will be slower.

The CG algorithm given by Hestenes and Stiefel is

$$\begin{aligned}
 \{p_0\} &= \{r_0\} = \{b\} - [K]\{x_0\} \\
 \alpha_i &= \frac{|\{r_i\}|^2}{\{p_i\}^T [K] \{p_i\}} \\
 \{x_{i+1}\} &= \{x_i\} + \alpha_i \{p_i\} \\
 i &= i+1 \\
 \{r_{i+1}\} &= \{r_i\} - \alpha_i [K] \{p_i\} \\
 \beta_i &= \frac{|\{r_{i+1}\}|^2}{|\{r_i\}|^2} \\
 \{p_{i+1}\} &= \{r_{i+1}\} + \beta_i \{p_i\}
 \end{aligned}
 \tag{21}$$

where $\{r\}$ is the residue vector, $\{p\}$ is a vector representing the direction in which $\{x\}$ is corrected, α is a scalar correction of the magnitude of $\{x\}$, and $[K]$ is the global stiffness matrix.

The matrix $[K]$ is shown in the algorithm but is not stored as an assembled global stiffness matrix in the computer. Instead, the matrix-vector products $\{Kx\}$ and $\{Kp\}$ are formed at the element level with $\{Kx\}$ determined once at the beginning and with $\{Kp\}$ formed for each iteration in the process.

2. Convergence Criteria

The equation solver uses two tests for convergence. First the residue vector must be less than unity. The second test is on strain energy; the change in strain energy normalized with strain energy must be less than a 'test value' specified by the user. Since this change in strain energy test is only a rate of convergence test, the final decision to accept a solution must be left to the user. References (3) and (5) can be used to estimate the accuracy of a solution for some classes of problems.

DESCRIPTION OF INPUT-OUTPUT DATA

The program consists of three or four FORTRAN job steps: (1) mesh generator (optional), (2) stiffness matrix formulation, (3) equation solver, and (4) stress calculations. Any one of the job steps can be run as a separate program provided the proper JCL is used. Input data for step (2) (Stiffness matrix formulation) can be from cards or passed from step (1) by card images on a sequential disk or tape unit. When data is passed from step (1) to step (2) by disk or tape, only one data card is required for step (2) to specify the disk or tape unit number. Data is passed from steps (2) to (3) and (3) to (4) by direct access data files only. One control data card each is required for job steps (3) and (4). Job step (3) can be restarted to break up jobs with long run times.

The program will handle four different types (called classes) of problem. The types are:

- Class 1 - linear elastic with constant material properties within an element
- Class 2 - linear elastic with material properties varying within an element
- Class 3 - linear thermal elastic with constant material properties within an element
- Class 4 - thermal elastic with temperature dependent material properties

A. Input Data for Step 2 (Stiffness matrix formulation)

1. Input unit card (I5) one card

Columns 1-5 unit number (specifies the unit which the input data will be read from, e.g., unit five will read data from cards)

2. Heading card¹ (10A8) one card

Columns 1-80 information to be printed with output

3. Control parameter card¹ (4I5, F10.2) one card

Columns 1-5 total number of nodal points

6-10 number of different materials

11-15 total number of elements

16-20 number of unique elements

21-30 initial temperature

4. Material data cards¹

A different material must be specified if any of the nine orthotropic constants, the fiber orientation, or the three thermal expansion coefficients are changed. Two cards are necessary for each material if the problem class is 1, 2, or 3. If the problem is class 4 then the nine elastic orthotropic constants are expressed as a function temperature. From one to nine sets of temperature-dependent elastic constants can be specified for each material. A linear interpolation is used to determine material properties between temperature-specified sets of elastic constants, and the material properties are assumed to be constant above the highest specified temperature and below the lowest specified temperature. The temperature-dependent cards must be in ascending order of temperatures.

First card (2I5, F10.2, 3F10.8) one for each material

Columns 1-5 material number (in sequential order)

6-10 number of temperature cards for this material

('1' for class 1, 2, or 3)

11-20 fiber orientation in degrees

21-30 thermal expansion coefficient, α_{11}

¹The word 'card' also implies card images on disk or tape

31-40 thermal expansion coefficient, α_{22}

41-50 thermal expansion coefficient, α_{33}

Subsequent cards (F5.0, 3F10.0, 3F5.2, 3F10.0) (One card for problem class 1, 2 or 3. And for problem class 4 one card for each temperature for which material properties are specified.)

Columns 1-5 temperature for material properties

(can be left blank for class 1 and 2 problems)

Columns 6-15 modulus of elasticity, E_{11} , KSI

16-25 modulus of elasticity, E_{22} , KSI

26-35 modulus of elasticity, E_{33} , KSI

36-40 Poisson's ratio, ν_{12}

41-45 Poisson's ratio, ν_{13}

46-50 Poisson's ratio, ν_{23}

51-60 shear modulus, G_{12} KSI

61-70 shear modulus, G_{13} KSI

71-80 shear modulus, G_{23} KSI

5. Element data cards¹ (1615) Two cards for each element. Figure 1 shows the element nodal numbers.

First card

Columns 1-5 element number (sequential)

6-10 global nodal number for element nodal number 1

11-15 global nodal number for element nodal number 2

(Global nodal numbers are put in fields of 5 columns for sequential element nodal numbers up to element nodal number 15 in columns 76-80.)

Second card

Columns 1-5 global nodal number for element nodal number 16

(Global nodal numbers are put in fields of 5 columns for sequential element nodal numbers up to element nodal number 24 in columns 41-45.)

46-50 material number

51-55 element type number

¹The word 'card' also implies card images on disk or tape

(Each unique element is given a type number.

The element types are numbered sequentially from one to the number of unique elements.)

56-60 class number (to specify type of thermal elastic problem)

'1' - elastic only, constant material properties within an element

'2' - elastic only, material properties can vary within an element

'3' - thermal elastic, material properties cannot vary with temperature within an element

'4' - thermal elastic, material properties can vary with temperature within an element

(Class 1 or 2 elements cannot be mixed with class 3 and 4 elements. Classes 1 and 2 can be mixed and classes 3 and 4 can be mixed.)

6. Nodal point cards¹ (I4,I4,I2, 6F10.6, F10.2) One card for each nodal point.

Columns 1-4 nodal point number (sequential)

5-8 material

(Only necessary if the material at this node is different from the material specified for the element. This nodal material will be ignored for elements of class 1, 3 or 4.)

9-10 boundary condition code

(There are eight possible combinations of force, F, and displacement, U, boundary conditions for the x, y, and z coordinates at each node.)

¹The word 'card' implies card images on disk or tape

'0'	F_x	F_y	F_z
'1'	U_x	F_y	F_z
'2'	U_x	U_y	F_z
'3'	U_x	F_y	U_z
'4'	F_x	U_y	F_z
'5'	F_x	F_y	U_z
'6'	F_x	U_y	U_z
'7'	U_x	U_y	U_z

11-20 x - coordinate (global system)

21-30 y - coordinate (global system)

31-40 z - coordinate (global system)

41-50 x - force or displacement boundary condition

51-60 y - force or displacement boundary condition

61-70 z - force or displacement boundary condition

71-80 final nodal temperature

(can be left blank for class 1 and 2 problems)

B. Card Input for Step 3 (Equation Solver)

Two different equation solvers are available. The first is an in-core version which is recommended for problems with less than four unique elements. The second version iterates from direct access disk and is recommended for problems with five or more unique elements.

Both versions use the same input data.

1. Parameter control card (2I5, 2F10.0, I5)

Columns 1-5 code number for initial guess of the displacement vector

'1' - The same initial guess for each degree of freedom. The value of the initial guess is specified in columns 11-20.

'2' - The initial guesses for the displacement vector are to be read in from cards in

hexadecimal, FORMAT (5Z16). The initial guesses will be multiplied by the number specified in columns 11-20.

'3' - The initial guesses for the displacement vector are to be read in from cards in hexadecimal, FORMAT (5Z16). The initial guesses in the z-direction only will be multiplied by the number specified in columns 11-20.

'4' - The initial guesses for the displacement vector are read in from a direct access data file created in a previous job.

6-10 maximum number of iterations for this run

11-20 For code number 1, this field contains the initial guess.

For code number 2, this field contains a multiplication factor for all the degrees of freedom (use '1.0' if the initial guesses are not to be modified.)

For code number 3, this field contains a multiplication factor for the z-direction displacements only.

For code number 4, this field is not used.

21-30 Convergence criterion factor (use .000001)

31-35 Print-punch control code for displacements

'0' - No printed or punched output

'1' - Printed output only — no punch

'2' - Punched output only — no print

'3' - Both printed and punched output

2. Displacement vector cards (5Z16)

The displacement vector deck is put behind the Parameter control card for code number 2 and 3 only.

C. Card Input for Step 4

1. Logic control card (15) one card

Columns 1-5 code to control printed displacements and stresses

'0' - Stresses printed in a rectangular coordinate system only

'1' - Stresses printed in a cylindrical coordinate system only

'2' - Displacements printed in a cylindrical coordinate system only

'3' - Both displacements and stresses printed in a cylindrical coordinate system

'4' - Both displacements and stresses printed in cylindrical coordinate system plus stresses in a rectangular coordinate system

D. Printed Output from Step 2

1. Problem parameters

2. Material properties

3. Local-to-global correlation matrix (element data)

a. EL NO - Element number

b. L _ _ - Lower _ _ _ _

c. U _ _ - Upper _ _ _ _

d. _ F _ - _ _ _ Front _ _ _

e. _ M _ - _ _ _ Middle _ _ _

f. _ B _ - _ _ _ Back _ _ _

g. MT - Material number

h. ET - Element type

i. C - Class

4. Nodal point data

a. NODE - Nodal number

b. MATL - Material number

c. CODE - Boundary condition code

- d. X-COORD - x-coordinate in global system
- e. Y-COORD - y-coordinate in global system
- f. Z-COORD - z-coordinate in global system
- g. X-DISPL/LOAD - Value of x boundary condition
- h. Y-DISPL/LOAD - Value of y boundary condition
- i. Z-DISPL/LOAD - Value of z boundary condition

E. Printed Output from Step 3

- 1. Convergence parameters
- 2. Displacements in rectangular coordinates

F. Printed Output from Step 4

- 1. Displacements in cylindrical coordinates
- 2. Stresses in cylindrical coordinates
- 3. Stresses in rectangular coordinates

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APPENDIX A

FORTRAN Listing of Program

Appendix contains the FORTRAN listing for:

STEP 2 - Stiffness matrix

STEP 3 - Equation solver
(Iteration in-core version)

STEP 3 - Equation solver
(Iteration from disk version)

STEP 4 - Stress components

C	MAIN PROGRAM STEP 2	MN2	10
C		MN2	20
C	*****	MN2	30
C	*	MN2	40
C	* STEP 2 PERFORMS FOUR FUNCTIONS	MN2	50
C	*	MN2	60
C	* 1. READS MESH AND BOUNDARY CONDITION DATA FROM CARDS OR	MN2	70
C	* CARD IMAGES	MN2	80
C	*	MN2	90
C	* 2. CALCULATES THE UNIQUE ELEMENT STIFFNESS MATRICES	MN2	100
C	*	MN2	110
C	* 3. CALCULATES THERMAL EQUIVALENT LOADS	MN2	120
C	*	MN2	130
C	* 4. WRITES MESH DATA, UNIQUE ELEMENT STIFFNESS MATRICES AND	MN2	140
C	* FORCE AND DISPLACEMENT BOUNDARY CONDITION VECTORS ON A	MN2	150
C	* DIRECT ACCESS DATA SET	MN2	160
C	*	MN2	170
C	*****	MN2	180
C		MN2	190
C	*****	MN2	200
C	*	MN2	210
C	* VARIABLE DEFINITIONS AND DIMENSIONS FOR STEP 2	MN2	220
C	*	MN2	230
C	* ALFA1(NMTL) - - - THERMAL EXPANSION COEFFICIENT 11	MN2	240
C	*	MN2	250
C	* ALFA2(NMTL) - - - THERMAL EXPANSION COEFFICIENT 22	MN2	260
C	*	MN2	270
C	* ALFA3(NMTL) - - - THERMAL EXPANSION COEFFICIENT 33	MN2	280
C	*	MN2	290
C	* AMBTMP - - - - - INITIAL TEMPERATURE	MN2	300
C	*	MN2	310
C	* DBC(NGNP) - - - - DISPLACEMENT BOUNDARY CONDITIONS	MN2	320
C	*	MN2	330
C	* E(NMTL,9,NTMP) - - MATERIAL PROPERTIES	MN2	340
C	* (1ST SUBSCRIPT - NUMBER OF MATERIALS)	MN2	350
C	* (2ND SUBSCRIPT - NUMBER OF ELASTIC CONSTANTS	MN2	360
C	* FOR AN ORTHOTROPIC MATERIAL)	MN2	370
C	* (3RD SUBSCRIPT - NUMBER OF TEMPERATURES THAT	MN2	380
C	* MATERIAL PROPERTIES CAN BE SPECIFIED FOR	MN2	390
C	* EACH MATERIAL	MN2	400
C	*	MN2	410
C	* FBC(NGNP) - - - - FORCE BOUNDARY CONDITIONS	MN2	420
C	*	MN2	430
C	* FIBORT(NMTL) - - - DIRECTION OF PRINCIPAL AXIS FOR EACH	MN2	440
C	* MATERIAL	MN2	450
C	*	MN2	460
C	* GNMAT(NEL,72) - - RELATES LOCAL AND GLOBAL DEGREES-OF-FREEDOM	MN2	470
C	*	MN2	480
C	* ICODE(NGNP) - - - BOUNDARY CONDITION CODE (FORCE OR	MN2	490
C	* DISPLACEMENT)	MN2	500
C	*	MN2	510

C	*	ICRD - - - - -	UNIT NUMBER FOR CARD READER	* MN2	520
C	*	IUDA - - - - -	UNIT NUMBER FOR DIRECT ACCESS FILE	* MN2	530
C	*	IUDA - - - - -	UNIT NUMBER FOR DIRECT ACCESS FILE	* MN2	540
C	*	IWRT - - - - -	UNIT NUMBER FOR PRINTER	* MN2	550
C	*	IWRT - - - - -	UNIT NUMBER FOR PRINTER	* MN2	560
C	*	IX(NIL,27) - - - -	RELATES LOCAL AND GLOBAL NODAL POINTS	* MN2	570
C	*	IX(NIL,27) - - - -	RELATES LOCAL AND GLOBAL NODAL POINTS	* MN2	580
C	*	LCBC(ND8C) - - - -	INDEX FOR DISPLACEMENT BOUNDARY CONDITIONS	* MN2	590
C	*	LCBC(ND8C) - - - -	INDEX FOR DISPLACEMENT BOUNDARY CONDITIONS	* MN2	600
C	*	MTLND(NGNP) - - - -	MATERIAL AT EACH NODE	* MN2	610
C	*	MTLND(NGNP) - - - -	MATERIAL AT EACH NODE	* MN2	620
C	*	ND8C - - - - -	NUMBER OF DISPLACEMENT BOUNDARY CONDITIONS	* MN2	630
C	*	ND8C - - - - -	NUMBER OF DISPLACEMENT BOUNDARY CONDITIONS	* MN2	640
C	*	NEL - - - - -	NUMBER OF ELEMENTS	* MN2	650
C	*	NEL - - - - -	NUMBER OF ELEMENTS	* MN2	660
C	*	NGLOF - - - - -	NUMBER OF DEGREES-OF-FREEDOM (GLOBAL SYSTEM)	* MN2	670
C	*	NGLOF - - - - -	NUMBER OF DEGREES-OF-FREEDOM (GLOBAL SYSTEM)	* MN2	680
C	*	NGNP - - - - -	NUMBER OF NODAL POINTS (GLOBAL SYSTEM)	* MN2	690
C	*	NGNP - - - - -	NUMBER OF NODAL POINTS (GLOBAL SYSTEM)	* MN2	700
C	*	NMTL - - - - -	NUMBER OF MATERIALS	* MN2	710
C	*	NMTL - - - - -	NUMBER OF MATERIALS	* MN2	720
C	*	NTMP(NMTL) - - - -	NUMBER OF MATERIAL PROPERTIES SPECIFIED FOR EACH MATERIAL	* MN2	730
C	*	NTMP(NMTL) - - - -	NUMBER OF MATERIAL PROPERTIES SPECIFIED FOR EACH MATERIAL	* MN2	740
C	*	NTMP(NMTL) - - - -	NUMBER OF MATERIAL PROPERTIES SPECIFIED FOR EACH MATERIAL	* MN2	750
C	*	NTMP(NMTL) - - - -	NUMBER OF MATERIAL PROPERTIES SPECIFIED FOR EACH MATERIAL	* MN2	760
C	*	NTYEL - - - - -	NUMBER OF UNIQUE ELEMENTS	* MN2	770
C	*	NTYEL - - - - -	NUMBER OF UNIQUE ELEMENTS	* MN2	780
C	*	S(2628) - - - - -	ELEMENT STIFFNESS MATRIX STORED AS ONE-DIMENSIONAL ARRAY	* MN2	790
C	*	S(2628) - - - - -	ELEMENT STIFFNESS MATRIX STORED AS ONE-DIMENSIONAL ARRAY	* MN2	800
C	*	THC(NEL,72) - - - -	THERMAL EQUIVALENT LOADS FOR EACH ELEMENT (NEL CAN BE DIMENSIONED AS '1' FOR NON-THERMAL PROBLEMS)	* MN2	810
C	*	THC(NEL,72) - - - -	THERMAL EQUIVALENT LOADS FOR EACH ELEMENT (NEL CAN BE DIMENSIONED AS '1' FOR NON-THERMAL PROBLEMS)	* MN2	820
C	*	THC(NEL,72) - - - -	THERMAL EQUIVALENT LOADS FOR EACH ELEMENT (NEL CAN BE DIMENSIONED AS '1' FOR NON-THERMAL PROBLEMS)	* MN2	830
C	*	THC(NEL,72) - - - -	THERMAL EQUIVALENT LOADS FOR EACH ELEMENT (NEL CAN BE DIMENSIONED AS '1' FOR NON-THERMAL PROBLEMS)	* MN2	840
C	*	THC(NEL,72) - - - -	THERMAL EQUIVALENT LOADS FOR EACH ELEMENT (NEL CAN BE DIMENSIONED AS '1' FOR NON-THERMAL PROBLEMS)	* MN2	850
C	*	TMPEL(NMTL,NTMP) -	TEMPERATURES AT WHICH MATERIAL PROPERTIES ARE SPECIFIED FOR EACH MATERIAL	* MN2	860
C	*	TMPEL(NMTL,NTMP) -	TEMPERATURES AT WHICH MATERIAL PROPERTIES ARE SPECIFIED FOR EACH MATERIAL	* MN2	870
C	*	TMPEL(NMTL,NTMP) -	TEMPERATURES AT WHICH MATERIAL PROPERTIES ARE SPECIFIED FOR EACH MATERIAL	* MN2	880
C	*	TMPEL(NMTL,NTMP) -	TEMPERATURES AT WHICH MATERIAL PROPERTIES ARE SPECIFIED FOR EACH MATERIAL	* MN2	890
C	*	TMPEL(NMTL,NTMP) -	TEMPERATURES AT WHICH MATERIAL PROPERTIES ARE SPECIFIED FOR EACH MATERIAL	* MN2	900
C	*	UX(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE X-DIRECTION	* MN2	910
C	*	UX(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE X-DIRECTION	* MN2	920
C	*	UX(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE X-DIRECTION	* MN2	930
C	*	UY(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE Y-DIRECTION	* MN2	940
C	*	UY(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE Y-DIRECTION	* MN2	950
C	*	UY(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE Y-DIRECTION	* MN2	960
C	*	UZ(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE Z-DIRECTION	* MN2	970
C	*	UZ(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE Z-DIRECTION	* MN2	980
C	*	UZ(NGNP) - - - - -	MAGNITUDE OF FORCE OR DISPLACEMENT BOUNDARY CONDITIONS IN THE Z-DIRECTION	* MN2	990
C	*	X(NGNP) - - - - -	X-COORDINATE (GLOBAL SYSTEM)	* MN2	1000
C	*	X(NGNP) - - - - -	X-COORDINATE (GLOBAL SYSTEM)	* MN2	1010
C	*	Y(NGNP) - - - - -	Y-COORDINATE (GLOBAL SYSTEM)	* MN2	1020

C	*		* MN2 1030
C	*	Z(NGNP) - - - - Z-COORDINATE (GLOBAL SYSTEM)	* MN2 1040
C	*		* MN2 1050
C	*	*****	* MN2 1060
C			MN2 1070
		IMPLICIT REAL*8 (A-H,O-Z)	MN2 1080
		LOGICAL*1 SW(12)	MN2 1090
		INTEGER*2 IX, ICODE, GNMAT, MTLND, LDBC	MN2 1100
		COMMON / GENL / XINIT, EPS, AMBTMP,	MN2 1110
	1	ICLASS, NEL, NGNP, NGLDF, NMTL, NTYEL, LIMIT, NM, NOBC	MN2 1120
		COMMON / NOELM/ X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	MN2 1130
	1	UZ(1015), THPND(1015), FBC(3045), DBC(3045), TBC(1,72),	MN2 1140
	2	ICODE(1015), IX(144,27), GNMAT(144,72),MTLND(1015),LDBC(1015)	MN2 1150
		COMMON /MATL / E(9,9,10), FIBORT(9), ALFA1(9),	MN2 1160
	1	ALFA2(9), ALFA3(9), TMEPL(9,10), NTMP(9)	MN2 1170
		COMMON /STIFEX/ S(2628)	MN2 1180
		COMMON / INDX / INEL, IGNP, ILNP,IMTL	MN2 1190
		COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE	MN2 1200
		OFFINE FILE 3(55,6500,U,IDXDA)	MN2 1210
		IUDA = 3	MN2 1220
		CALL INPT12	MN2 1230
		NGLDF = 3 * NGNP	MN2 1240
C			MN2 1250
C		CHANGE NODAL POINT NUMBERING SYSTEM TO DEGREE-OF-FREEDOM	MN2 1260
C		NUMBERING SYSTEM	MN2 1270
C			MN2 1280
		DO 14 INEL=1,NEL	MN2 1290
		DO 14 J=1,24	MN2 1300
		GNMAT(INEL,3*J-2) = 3*IX(INEL,J)-2	MN2 1310
		GNMAT(INEL,3*J-1) = 3*IX(INEL,J)-1	MN2 1320
	14	GNMAT(INEL,3*J) = 3*IX(INEL,J)	MN2 1330
C			MN2 1340
C		ZERO THERMAL LOAD MATRIX	MN2 1350
C			MN2 1360
		IF(IX(1,27) .EQ. 1 .OR. IX(1,27) .EQ. 2) GO TO 5	MN2 1370
		DO 15 I=1,NTYEL	MN2 1380
		DO 15 J=1,72	MN2 1390
	15	TBC(I,J) = GDO	MN2 1400
C			MN2 1410
C		CALCULATE AND STORE UNIQUE STIFFNESS MATRICES	MN2 1420
C			MN2 1430
	5	IDXDA = 7	MN2 1440
		DO 12 I =1,NTYEL	MN2 1450
		DO 20 INEL=1,NEL	MN2 1460
		IF(IX(INEL,26) .EQ. 1) GO TO 6	MN2 1470
	20	CONTINUE	MN2 1480
	6	CALL ELSTIF	MN2 1490
		WRITE(IUDA,IDXDA) (S(J),J=1,2628)	MN2 1500
	12	CONTINUE	MN2 1510
C			MN2 1520
C		FORM FORCE AND DISPLACEMENT VECTORS FROM BOUNDARY CONDITION DATA	MN2 1530

C	DO 1 I=1,NGLOF	MN2 1540
	DBR(1) = 0.00	MN2 1550
	1 FBC(1) = 0.00	MN2 1560
	CALL FBCDBC	MN2 1570
C		MN2 1580
C	COMBINE STATIC AND THERMAL LOADS	MN2 1590
C		MN2 1600
	IF(IX(1,27) .EQ. 1 .OR. IX(1,27) .EQ. 2) GO TO 7	MN2 1610
	DO 17 INEL=1,NEL	MN2 1620
	IX26 = IX(INEL,26)	MN2 1630
	DO 17 I=1,72	MN2 1640
	17 FBC(GNMAT(INEL,I)) = FBC(GNMAT(INEL,I)) + TBC(IX26,I)	MN2 1650
	7 DO 46 J=1,12	MN2 1660
	46 SW(J) = .FALSE.	MN2 1670
C		MN2 1680
C	WRITE PROBLEM DATA ON DISK TO BE PAST TO THE NEXT STEP	MN2 1690
C		MN2 1700
	WRITE(IUDA*1) NEL, NGLOF, NDBC, NTYEL, LIMIT, NGNP, NMTL,	MN2 1710
	1 HED, IPAGE, AMBTMP	MN2 1720
	WRITE(IUDA*2) ((NTMP(J), FIBORT(J), ALFA1(J), ALFA2(J), ALFA3(J)),	MN2 1730
	1 TMPCL(J,I), (E(J,L,1),L=1,9), I=1,10), J=1,NMTL)	MN2 1740
	2 , ((IX(1,J),J=1,27),I=1,NEL),	MN2 1750
	3 (TMPND(J), MTLND(J),J=1,NGNP)	MN2 1760
	WRITE(IUDA*3) , (X(J)-J=1,NGNP), (Y(J),J=1,NGNP), (Z(J),J=1,NGNP)	MN2 1770
	WRITE(IUDA*4) (FBC(J),J=1,NGLOF)	MN2 1780
	1 , SW, NDCNV, (LDBC(J),J=1,NDBC)	MN2 1790
	WRITE(IUDA*5) (DBC(J),J=1,NGLOF)	MN2 1800
	1 , (IX(J,26),J=1,NEL)	MN2 1810
	WRITE(IUDA*6) ((GNMAT(1,J),J=1,72),I=1,NEL)	MN2 1820
	STOP	MN2 1830
	END	MN2 1840
		MN2 1850

C	SUBROUTINE INPT12	IN2	10
C	*****	IN2	20
C	*****	IN2	30
C	*****	IN2	40
C	* SUBROUTINE INPT12 READS MESH AND BOUNDARY CONDITION DATA FROM	* IN2	50
C	* CARDS OR CARD IMAGES AND PRINTS INPUT DATA	* IN2	60
C	*****	* IN2	70
C	* THIS SUBROUTINE IS CALLED BY -	* IN2	80
C	* MAIN	* IN2	90
C	*****	* IN2	100
C	* THIS SUBROUTINE CALLS -	* IN2	110
C	* TITLE	* IN2	120
C	*****	* IN2	130
C	*****	* IN2	140
C	*****	IN2	150
	IMPLICIT REAL*8 (A-H,O-Z)	IN2	160
	INTEGER*2 IX, ICODE, GNMAT, MTLND, LOBC	IN2	170
	COMMON / GENL / XINIT, EPS, AMBTMP,	IN2	180
	1 ICLASS, NEL, NGNP, NGLDF, NHTL, NTYEL, LIMIT, NM, NDBC	IN2	190
	COMMON / NODELM/ X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	IN2	200
	1 UZ(1015), TMPND(1015), FBC(3045), DBC(3045), TRC(1,72),	IN2	210
	2 ICODE(1015), IX(144,27), GNMAT(144,72), MTLND(1015), LOBC(1015)	IN2	220
	COMMON / MATL / E(9,9,10), FIBORT(9), ALFA1(9),	IN2	230
	1 ALFA2(9), ALFA3(9), TMEPL(9,10), NTMP(9)	IN2	240
	COMMON / HEAD / HED(10),ICRD,IMRT,IPAGE,LINE	IN2	250
	1000 FORMAT(16I5)	IN2	260
	1001 FORMAT(2I5, F10.2, 3F10.8)	IN2	270
	1002 FORMAT(F5.0, 3F10.0, 3F5.2, 3F10.0)	IN2	280
	1003 FORMAT(I4, I4, I2, 6F10.6, F10.2)	IN2	290
	1004 FORMAT(10A8)	IN2	300
	1005 FORMAT(4I5, F10.2)	IN2	310
	2001 FORMAT(// '0 MATERIAL NO. FIBER ORT. THERMAL EXPAN. CIN2	IN2	320
	10EF. 11 THERMAL EXPAN COEF. 22 THERMAL EXPAN.COEF. 33')	IN2	330
	2002 FORMAT ('0', 4X, I5, I3X, F5.1, I0X, G16.7, I3X, G16.7, I3X, G16.7 /	IN2	340
	1 '0', 20X, 'TEMP E11 E22 E33 NU12	IN2	350
	2 NU13 NU23 G12 G13 G23')	IN2	360
	2003 FORMAT(19X, 4(F7.1,3X), 3(F7.2,3X), 3(F7.1,3X))	IN2	370
	2004 FORMAT('0 NODE MATL CODE X-COORD Y-COORD Z-COORD	IN2	380
	1 X-DISPL/LOAD Y-DISPL/LOAD Z-DISPL/LOAD TEMPERATURE')	IN2	390
	2005 FORMAT (1X, 2I5, I3, 3X, G13.6, 6(2X, G13.6))	IN2	400
	2006 FORMAT('0EL NO LF1 LF2 LF3 LF4 UF1 UF2 UF3 UF4 LM1 LM2	IN2	410
	1LM3 LM4 UM1 UM2 UM3 UM4 LB1 LB2 LB3 LB4 UB1 UB2 UB3	IN2	420
	2B4 MT ET C')	IN2	430
	2007 FORMAT (2X, I3, 24I5, 2I3, I2)	IN2	440
	2008 FORMAT('0DATA FOR THIS STEP IS READ IN ON UNIT', I3)	IN2	450
	2013 FORMAT('0PROBLEM CONSTANTS' /	IN2	460
	1 ' NUMBER OF NODAL POINTS', T45, 15/	IN2	470
	2 ' NUMBER OF MATERIALS', T45, 15/	IN2	480
	2 ' NUMBER OF ELEMENTS', T45, 15/	IN2	490
	3 ' NUMBER OF TYPES OF ELEMENTS', T45, 15/	IN2	500
	4 ' AMB. TEMPERATURE', T37,E13.7)	IN2	510

C		IN2	520
C	READ IN PROBLEM DATA	IN2	530
C		IN2	540
	IPAGE = 1	IN2	550
	READ(5,1000) INDAT	IN2	560
	READ(INDAT,1004) HED	IN2	570
	READ(INDAT,1005) NGNP, NMTL, NEL, NTYEL, AMBTMP	IN2	580
C		IN2	590
C	PRINT PROBLEM DATA	IN2	600
C		IN2	610
	CALL TITLE	IN2	620
	WRITE(IWRT,2008) INDAT	IN2	630
	15 WRITE(IWRT,2013) NGNP, NMTL, NEL, NTYEL, AMBTMP	IN2	640
C		IN2	650
C	READ IN MATERIAL DATA	IN2	660
C		IN2	670
	DO 10 IMTL=1,NMTL	IN2	680
	READ(INDAT,1001) MTLN, NTMP(IMTL), FIBORT(IMTL), ALFA1(IMTL),	IN2	690
	1 ALFA2(IMTL), ALFA3(IMTL)	IN2	700
	NTMP1 = NTMP(IMTL)	IN2	710
	DO 10 ITMP=1,NTMP1	IN2	720
	10 READ(INDAT,1002) TMPEL(IMTL,ITMP), (E(IMTL,J,ITMP),J=1,9)	IN2	730
C		IN2	740
C	PRINT MATERIAL DATA	IN2	750
C		IN2	760
	CALL TITLE	IN2	770
	DO 50 IMTL=1,NMTL	IN2	780
	IF(LINE +.NTMP(IMTL) .LT. 50) GO TO 1	IN2	790
	CALL TITLE	IN2	800
	1 WRITE(IWRT,2001)	IN2	810
	LINE = LINE + 3	IN2	820
	WRITE(IWRT,2002) IMTL, FIBORT(IMTL), ALFA1(IMTL), ALFA2(IMTL),	IN2	830
	1 ALFA3(IMTL)	IN2	840
	LINE = LINE+1	IN2	850
	NTMP1 = NTMP(IMTL)	IN2	860
	DO 50 ITMP=1,NTMP1	IN2	870
	LINE = LINE+1	IN2	880
	50 WRITE(IWRT,2003) TMPEL(IMTL,ITMP), (E(IMTL,J,ITMP),J=1,9)	IN2	890
C		IN2	900
C	READ IN ELEMENT DATA	IN2	910
C		IN2	920
	DO 30 INEL=1,NEL	IN2	930
	30 READ(INDAT,1000) M, (IX(M,J),J=1,27)	IN2	940
C		IN2	950
C	PRINT ELEMENT DATA	IN2	960
C		IN2	970
	CALL TITLE	IN2	980
	WRITE(IWRT,2006)	IN2	990
	DO 70 INEL=1,NEL	IN2	1000
	IF(LINE .LT. 45) GO TO 3	IN2	1010
	CALL TITLE	IN2	1020

WRITE(IWRT, 2006)	IN2 1030
3 LINE=LINE+1	IN2 1040
70 WRITE(IWRT,2007) INEL, (IX(INEL,J),J=1,27)	IN2 1050
C	IN2 1060
C READ IN NODAL POINT DATA	IN2 1070
C	IN2 1080
DO 40 IGNP=1,NGNP	IN2 1090
40 READ(INDAT,1003) M, MTLND(M), ICODE(M), X(M), Y(M), Z(M),	IN2 1100
1 UX(M), UY(M), UZ(M), TMPND(M)	IN2 1110
C	IN2 1120
C PRINT NODAL POINT DATA	IN2 1130
C	IN2 1140
CALL TITLE	IN2 1150
WRITE(IWRT,2004)	IN2 1160
DO 60 IGNP=1,NGNP	IN2 1170
IF(LINE .LT. 45) GO TO 2	IN2 1180
CALL TITLE	IN2 1190
WRITE(IWRT,2004)	IN2 1200
2 LINE = LINE+1	IN2 1210
WRITE(IWRT,2005) IGNP, MTLND(IGNP), ICODE(IGNP), X(IGNP), Y(IGNP)	IN2 1220
1 , Z(IGNP), UX(IGNP), UY(IGNP), UZ(IGNP), TMPND(IGNP)	IN2 1230
60 CONTINUE	IN2 1240
RETURN	IN2 1250
END	IN2 1260

	SUBROUTINE TITLE	T12	10
C		T12	20
C	* * * * *	T12	30
C	*	* T12	40
C	* SUBROUTINE TITLE PRINTS THE HEADING ON EACH PRINTED PAGE	* T12	50
C	*	* T12	60
C	* THIS SUBROUTINE IS CALLED BY -	* T12	70
C	* INPT12	* T12	80
C	*	* T12	90
C	* * * * *	* T12	100
C		T12	110
	IMPLICIT REAL*8 (A-H,O-Z)	T12	120
	COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE	T12	130
100	FORMAT (1H1,'FEM 72-DOF GENERAL HEXAHEDRONS THERMO-ELASTIC, VARYIN	T12	140
	1G MATERIAL PROPERTIES, DANA', 9X, 'PAGE', 13)	T12	150
101	FORMAT (1H0,10A8)	T12	160
	LIST = 6	T12	170
	IWRT = 6	T12	180
	WRITE (LIST,100) IPAGE	T12	190
	WRITE (LIST,101) HED	T12	200
	IPAGE= IPAGE +1	T12	210
	LINE = 0	T12	220
	RETURN	T12	230
	END	T12	240

	SUBROUTINE ELSTIF	ES2	10
C		ES2	20
C	* * * * *	ES2	30
C	*	ES2	40
C	* SUBROUTINE ELSTIF CALCULATES THE ELEMENT STIFFNESS MATRICES.	ES2	50
C	* ONLY THE UPPER SYMMETRIC PORTION IS FORMED.	ES2	60
C	* EACH MATRIX IS STORED AS A ONE-DIMENSIONAL ARRAY.	ES2	70
C	*	ES2	80
C	* THIS SUBROUTINE IS CALLED BY -	ES2	90
C	* MAIN	ES2	100
C	*	ES2	110
C	* THIS SUBROUTINE CALLS -	ES2	120
C	* FLAS	ES2	130
C	* BMAT	ES2	140
C	* SHPFNT	ES2	150
C	*	ES2	160
C	* * * * *	ES2	170
C		ES2	180
	IMPLICIT REAL*8 (A-H,O-Z)	ES2	190
	INTEGER*2 IX, ICODE, GNMAT, MTLND, LOBC	ES2	200
	COMMON / GENL / XINIT, EPS, AMBTMP,	ES2	210
	1 ICLASS, NEL, NGNP, NGLOF, NHTL, NTYEL, LIMIT, NM, NOBC	ES2	220
	COMMON /MODEL/ X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	ES2	230
	1 UZ(1015), TMPND(1015), FBC(3045), DBC(3045), TBC(1,72),	ES2	240
	2 ICODE(1015), IX(144,27), GNMAT(144,72),MTLND(1015),LOBC(1015)	ES2	250
	COMMON /MATL / E(9,9,10), FIBORT(9), ALFA1(9),	ES2	260
	1 ALFA2(9), ALFA3(9), TMPL(9,10), NTMP(9)	ES2	270
	COMMON /STIFEX/ S(2628)	ES2	280
	COMMON / STIFIN / D(6,6,24), XNVCT(24), ETM(9), BA(6,72),	ES2	290
	1 C(3,24), XYZ(24,3), ALFTMP(6), XSIK, ETAJ, ZTAI	ES2	300
	COMMON / INDX / INEL, IGNP, ILNP,IMTL	ES2	310
	DIMENSION DSHP(6,6), BTD(72,6), BDR(2628)	ES2	320
	DIMENSION H(32),XSI(4),ETA(4),ZTA(2),W(4),WW(2)	ES2	330
C		ES2	340
C	FORM ELEMENT STIFFNESS MATRIX BY NUMERICAL INTEGRATION WITH GAUSS QUAD	ES2	350
C	RATURE FORMULAR, S(72X72) = H*(BT*D*B)*DETJ AT EACH G.P., 4X4X2 RULE	ES2	360
C	SET GAUSS PTS FOR GENERAL HEXAHEDRON IN NUM. INT. WITH 4X4X2 RULE	ES2	370
C		ES2	380
	XSI(4) = .861136311594053D0	ES2	390
	XSI(3) = .339981043584856D0	ES2	400
	XSI(2) = -XSI(3)	ES2	410
	XSI(1) = -XSI(4)	ES2	420
	ZTA(2) = .577350269189626D0	ES2	430
	ZTA(1) = -ZTA(2)	ES2	440
	DO 10 I=1,4	ES2	450
	10 ETA(I) = XSI(I)	ES2	460
C		ES2	470
C	FORM WEIGHING COEFFICIENTS H(32) AT GAUSS POINT	ES2	480
C		ES2	490
	W(1)=.347854845137454D0	ES2	500
	W(2)=.652145154862546D0	ES2	510

W(3) = W(2)	ES2 520
W(4) = W(1)	ES2 530
WW(1) = 1.00	ES2 540
W(2) = 1.00	ES2 550
DO 15 I=1,4	ES2 560
DO 15 J=1,4	ES2 570
DO 15 K=1,2	ES2 580
M = K + 2*(J - 1) + 8*(I - 1)	ES2 590
15 H(M) = W(I)*W(J)*WW(K)	ES2 600
C	ES2 610
C FORM NODAL PT. COORD.S MATRIX XYZ AND C FOR J(3X3) = J(3X24)*XYZ(24X3)	ES2 620
C	ES2 630
DO 20 I=1,24	ES2 640
L = IX(INEL,I)	ES2 650
XYZ(I,1) = X(L)	ES2 660
XYZ(I,2) = Y(L)	ES2 670
20 XYZ(I,3) = Z(L)	ES2 680
C	ES2 690
C CALCULATE ELASTIC PROPERTIES	ES2 700
C	ES2 710
CALL ELAS	ES2 720
DO 25 NL=1,2628	ES2 730
25 S(NL) = 0.00	ES2 740
DO 100 K=1,4	ES2 750
DO 100 J=1,4	ES2 760
DO 100 I=1,2	ES2 770
M = I + 2*(J - 1) + 8*(K - 1)	ES2 780
XSIK = XSI(K)	ES2 790
ETAJ = ETA(J)	ES2 800
ZTAI = ZTA(I)	ES2 810
C	ES2 820
C FORM B MATRIX	ES2 830
C	ES2 840
CALL BMA(I,J,K,DETJ)	ES2 850
IF(IX(INEL,27) .EQ. 1) GO TO 1	ES2 860
CALL SHPFNT	ES2 870
IF(IX(INEL,27) .EQ. 3) GO TO 1	ES2 880
C	ES2 890
C FORM 3-D ELASTIC MATERIAL PROPERTIES ARRAY (USED ONLY IF ELASTIC	ES2 900
C PROPERTIES VARY WITHIN AN ELEMENT)	ES2 910
C	ES2 920
DO 110 N=1,6	ES2 930
DO 110 L=1,6	ES2 940
DSHP(L,N) = 000	ES2 950
DO 110 ILNP=1,24	ES2 960
110 DSHP(L,N) = DSHP(L,N) + D(L,N,ILNP) * XNVCT(ILNP)	ES2 970
GO TO 4	ES2 980
1 DO 120 N=1,6	ES2 990
DO 120 L=1,6	ES2 1000
120 USHP(L,N) = D(L,N,1)	ES2 1010
4 CONTINUE	ES2 1020

DO 80 N=1,72	ES2 1030
DO 80 L=1,6	ES2 1040
BTD(N,L) = 0.00	ES2 1050
DO 80 NN=1,6	ES2 1060
80 BTD(N,L) = BTD(N,L) + BA(NN,N)*DSHP(NN,L)	ES2 1070
IF(IX(INEL,27) .EQ. 1 .OR. IX(INEL,27) .EQ. 2) GO TO 5	ES2 1080
C	ES2 1090
C CALCULATE THERMAL-EQUIVALENT LOAD VECTOR FOR EACH ELEMENT (THERMAL	ES2 1100
C PROBLEM ONLY)	ES2 1110
C	ES2 1120
TMP = 0.00	ES2 1130
DO 130 ILNP=1,24	ES2 1140
130 TMP = TMP + TMPND(IX(INEL,ILNP))* XNVCT(ILNP)	ES2 1150
TMP = TMP - AMBTMP	ES2 1160
IX26 = IX(INEL,26)	ES2 1170
DO 140 L=1,72	ES2 1180
DO 140 N=1,6	ES2 1190
140 TBC(IX26,L) = TBC(IX26,L) + TMP*ALFTMP(N)*BTD(L,N)*H(M)*DETJ	ES2 1200
5 NL = 0	ES2 1210
C	ES2 1220
C FORM TRIPLE MATRIX PRODUCT	ES2 1230
C	ES2 1240
DO 90 N=1,72	ES2 1250
DO 90 L=N,72	ES2 1260
NL = NL + 1	ES2 1270
BDB(NL) = 0.00	ES2 1280
DO 90 NN=1,6	ES2 1290
90 BDB(NL) = BDB(NL) + BTD(N,NN)*BA(NN,L)	ES2 1300
NL=0	ES2 1310
DO 100 N=1,72	ES2 1320
DO 100 L=N,72	ES2 1330
NL = NL + 1	ES2 1340
100 S(NL) = S(NL) + H(M) * DETJ*BDB(NL)	ES2 1350
RETURN	ES2 1360
END	ES2 1370

	SUBROUTINE ELAS	EL2	10
C		EL2	20
C	*****	EL2	30
C	*	EL2	40
C	* SUBROUTINE ELAS, IN CONJUNCTION WITH DMAT, CALCULATES THE	EL2	50
C	* ELASTIC MATRIX FOR EACH ELEMENT	EL2	60
C	*	EL2	70
C	* THIS SUBROUTINE IS CALLED BY -	EL2	80
C	* ELSTIF	EL2	90
C	*	EL2	100
C	* THIS SUBROUTINE CALLS -	EL2	110
C	* DMAT	EL2	120
C	*	EL2	130
C	*****	EL2	140
	IMPLICIT REAL*8 (A-H,O-Z)	EL2	150
	INTEGER*2 IX, ICODE, GNMAT, MTLND, LDBC	EL2	160
	COMMON / GENL / XINIT, EPS, AMBTMP,	EL2	170
	1 ICLASS, NEL, NGNP, NGLOF, NMTL, NTYEL, LIMIT, NM, NDBC	EL2	180
	COMMON / NOELM / X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	EL2	190
	1 UZ(1015), TMPND(1015), FBC(3045), DBC(3045), TBC(1,72),	EL2	200
	2 ICODE(1015), IX(144,27), GNMAT(144,72), MTLND(1015), LDBC(1015)	EL2	210
	COMMON / MATL / E(9,9,10), FIBORT(9), ALFA1(9),	EL2	220
	1 ALFA2(9), ALFA3(9), TMPEL(9,10), NTMP(9)	EL2	230
	COMMON / INDX / INEL, IGNP, ILNP, IMTL	EL2	240
	COMMON / STIFIN / D(6,6,24), XNVCT(24), ETH(9), BA(6,72),	EL2	250
	1 C(3,24), XYZ(24,3), ALFTMP(6), XSIK, ETAJ, ZTAI	EL2	260
	IF(IX(INEL,27) .EQ. 1 .OR. IX(INEL,27) .EQ. 3) GO TO 31	EL2	270
	IF(IX(INEL,27) .EQ. 2) GO TO 2	EL2	280
	NTMP1 = NTMP(IX(INEL,25))	EL2	290
	IF(NTMP1 .EQ. 1) GO TO 31	EL2	300
	DO 10 ILNP=1,24	EL2	310
	IMTL = MTLND(IX(INEL,ILNP))	EL2	320
	IF(IMTL .EQ. 0) IMTL = IX(INEL,25)	EL2	330
	IGNT = IX(INEL,ILNP)	EL2	340
	IF(TMPND(IGNT) .LT. TMPEL(IMTL,1)) GO TO 5	EL2	350
	IF(TMPND(IGNT) .GE. TMPEL(IMTL,NTMP(IMTL))) GO TO 6	EL2	360
	NTMP1 = NTMP(IMTL) - 1	EL2	370
	DO 20 II=1,NTMP1	EL2	380
	IF(TMPND(IGNT).GT. TMPEL(IMTL,II) .AND. TMPND(IGNT).LE.	EL2	390
	1 TMPEL(IMTL,II+1)) GO TO 4	EL2	400
	20 CONTINUE	EL2	410
	5 DO 30 I=1,9	EL2	420
	30 ETH(I) = E(IMTL,I,1)	EL2	430
	GO TO 1	EL2	440
	6 DO 40 I=1,9	EL2	450
	40 ETH(I) = E(IMTL,I,NTMP(IMTL))	EL2	460
	GO TO 1	EL2	470
	4 DIFTP1 = TMPEL(IMTL,II+1) - TMPEL(IMTL,II)	EL2	480
	DIFTP2 = TMPND(IGNT) - TMPEL(IMTL,II)	EL2	490
	RATDIF = DIFTP2 / DIFTP1	EL2	500
		EL2	510

DO 50 I=1,9	EL2 520
50 ETH(I) = E(IMTL,I,II) + RATDIF * (E(IMTL,I,II+1) - E(IMVL,I,II))	EL2 530
CALL DMAT	EL2 540
10 CONTINUE	EL2 550
RETURN	EL2 560
31 IMTL = IX(INEL,25)	EL2 570
ILNP = 1	EL2 580
DO 60 I=1,9	EL2 590
60 ETH(I) = E(IMTL,I,1)	EL2 600
CALL DMAT	EL2 610
RETURN	EL2 620
2 DO 70 ILNP=1,24	EL2 630
IMTL = MTLND(IX(INEL,ILNP))	EL2 640
IF(IMTL.EQ. 0) IMTL = IX(INEL,25)	EL2 650
DO 80 I=1,9	EL2 660
80 ETH(I) = E(IMTL,I,1)	EL2 670
70 CALL DMAT	EL2 680
RETURN	EL2 690
END	EL2 700

	SUBROUTINE BMAT(I,J,K,DETJ)	BM2 10
C		BM2 20
C	* * *	BM2 30
C	* * *	BM2 40
C	* SUBROUTINE BMAT FORMS THE B MATRIX WHICH IS USED IN CONJUNCTION	BM2 50
C	* WITH THE ELASTIC MATRIX TO FORM THE STIFFNESS MATRIX	BM2 60
C	* * *	BM2 70
C	* THIS SUBROUTINE IS CALLED BY -	BM2 80
C	* ELSTIF	BM2 90
C	* * *	BM2 100
C	* * *	BM2 110
C		BM2 120
	IMPLICIT REAL*8 (A-H,O-Z)	BM2 130
	INTEGER*2 IX, ICODE, GNMAT, MTLND, LDBC	BM2 140
	COMMON / GENL / XINIT, EPS, AMBTMP,	BM2 150
	1 ICLASS, NEL, NGNP, NGLDF, NMTL, NTYEL, LIMIT, NM, NDBC	BM2 160
	COMMON / MODEL / X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	BM2 170
	1 UZ(1015), TMPND(1015), FRC(3045), DBC(3045), TBC(1,72),	BM2 180
	2 ICODE(1015), IX(144,27), GNMAT(144,72), MTLND(1015), LDBC(1015)	BM2 190
	COMMON / MATL / E(9,9,10), FIBORT(9), ALFA1(9),	BM2 200
	1 ALFA2(9), ALFA3(9), TMPEL(9,10), NTMP(9)	BM2 210
	COMMON / STIFIN / D(6,6,24), XNVCT(24), ETH(9), BA(6,72),	BM2 220
	1 C(3,24), XYZ(24,3), ALFTMP(6), XSIK, ETAJ, ZTAI	BM2 230
	COMMON / INDX / INEL, IGNP, ILNP, IMTL	BM2 240
	DIMENSION DJ(3,3), DJI(3,3), XSI(4), ETA(4), ZTA(2)	BM2 250
	XSI(K) = XSIK	BM2 260
	ETA(J) = ETAJ	BM2 270
	ZTA(I) = ZTAI	BM2 280
C		BM2 290
C	FORM C MATRIX	BM2 300
C		BM2 310
	C(1,1) = (1.00 - ETA(J))*(1.00 - ZTA(I))*(10.00 + 18.00*XSI(K) -	BM2 320
	1 27.00*XSI(K)**2 - 9.00*ETA(J)**2)	BM2 330
	C(1,2) = (1.00 - ETA(J))*(1.00 - ZTA(I))*(81.00*XSI(K)**2	BM2 340
	1 -18.00*XSI(K) - 27.00)	BM2 350
	C(1,3) = (1.00 - ETA(J))*(1.00 - ZTA(I))*(27.00 - 18.00*XSI(K) -	BM2 360
	1 81.00*XSI(K)**2)	BM2 370
	C(1,4) = (1.00 - ETA(J))*(1.00 - ZTA(I))*(27.00*XSI(K)**2 +	BM2 380
	1 9.00*ETA(J)**2 + 18.00*XSI(K) - 10.00)	BM2 390
	C(1,5) = (1.00 - ETA(J))*(1.00 + ZTA(I))*(10.00 + 18.00*XSI(K) -	BM2 400
	1 27.00*XSI(K)**2 - 9.00*ETA(J)**2)	BM2 410
	C(1,6) = (1.00 - ETA(J))*(1.00 + ZTA(I))*(81.00*XSI(K)**2	BM2 420
	1 -18.00*XSI(K) - 27.00)	BM2 430
	C(1,7) = (1.00 - ETA(J))*(1.00 + ZTA(I))*(27.00 - 18.00*XSI(K) -	BM2 440
	1 81.00*XSI(K)**2)	BM2 450
	C(1,8) = (1.00 - ETA(J))*(1.00 + ZTA(I))*(27.00*XSI(K)**2 +	BM2 460
	1 9.00*ETA(J)**2 + 18.00*XSI(K) - 10.00)	BM2 470
	C(1,9) = (1.00-3.00*ETA(J))*(1.00-ZTA(I))*(9.00*ETA(J)**2-9.00)	BM2 480
	C(1,10) = (1.00+3.00*ETA(J))*(1.00-ZTA(I))*(9.00*ETA(J)**2-9.00)	BM2 490
	C(1,11) = -C(1,9)	BM2 500
	C(1,12) = -C(1,10)	BM2 510

C(1,13)= (1.00-3.00*ETA(J))*(1.00+ZTA(I))*(9.00*ETA(J)**2-9.00)	BM2	520
C(1,14)= (1.00+3.00*ETA(J))*(1.00+ZTA(I))*(9.00*ETA(J)**2-9.00)	BM2	530
C(1,15)= -C(1,13)	BM2	540
C(1,16)= -C(1,14)	BM2	550
C(1,17)= (1.00 + ETA(J))*(1.00 - ZTA(I))*(10.00 + 18.00*XSI(K) -	BM2	560
1 27.00*XSI(K)**2 - 9.00*ETA(J)**2)	BM2	570
C(1,18)= (1.00 + ETA(J))*(1.00 - ZTA(I))*(81.00*XSI(K)**2	BM2	580
1 -18.00*XSI(K) - 27.00)	BM2	590
C(1,19)= (1.00 + ETA(J))*(1.00 - ZTA(I))*(27.00 - 18.00*XSI(K) -	BM2	600
1 81.00*XSI(K)**2)	BM2	610
C(1,20)= (1.00 + ETA(J))*(1.00 - ZTA(I))*(27.00*XSI(K)**2 +	BM2	620
1 9.00*ETA(J)**2 + 18.00*XSI(K) - 10.00)	BM2	630
C(1,21)= (1.00 + ETA(J))*(1.00 + ZTA(I))*(10.00 + 18.00*XSI(K) -	BM2	640
1 27.00*XSI(K)**2 - 9.00*ETA(J)**2)	BM2	650
C(1,22)= (1.00 + ETA(J))*(1.00 + ZTA(I))*(81.00*XSI(K)**2	BM2	660
1 -18.00*XSI(K) - 27.00)	BM2	670
C(1,23)= (1.00 + ETA(J))*(1.00 + ZTA(I))*(27.00 - 18.00*XSI(K) -	BM2	680
1 81.00*XSI(K)**2)	BM2	690
C(1,24)= (1.00 + ETA(J))*(1.00 + ZTA(I))*(27.00*XSI(K)**2 +	BM2	700
1 9.00*ETA(J)**2 + 18.00*XSI(K) - 10.00)	BM2	710
C(2,1)= (1.00 - XSI(K))*(1.00 - ZTA(I))*(10.00 + 18.00*ETA(J) -	BM2	720
1 9.00*XSI(K)**2 - 27.00*ETA(J)**2)	BM2	730
C(2,2)= (1.00 - 3.00*XSI(K))*(1.00 - ZTA(I))*(9.00*XSI(K)**2-9.00)	BM2	740
C(2,3)= (1.00 + 3.00*XSI(K))*(1.00 - ZTA(I))*(9.00*XSI(K)**2-9.00)	BM2	750
C(2,4)= (1.00 + XSI(K))*(1.00 - ZTA(I))*(10.00 + 18.00*ETA(J) -	BM2	760
1 9.00*XSI(K)**2 - 27.00*ETA(J)**2)	BM2	770
C(2,5)= (1.00 - XSI(K))*(1.00 + ZTA(I))*(10.00 + 18.00*ETA(J) -	BM2	780
1 9.00*XSI(K)**2 - 27.00*ETA(J)**2)	BM2	790
C(2,6)= (1.00 - 3.00*XSI(K))*(1.00 + ZTA(I))*(9.00*XSI(K)**2-9.00)	BM2	800
C(2,7)= (1.00 + 3.00*XSI(K))*(1.00 + ZTA(I))*(9.00*XSI(K)**2-9.00)	BM2	810
C(2,8)= (1.00 + XSI(K))*(1.00 + ZTA(I))*(10.00 + 18.00*ETA(J) -	BM2	820
1 9.00*XSI(K)**2 - 27.00*ETA(J)**2)	BM2	830
C(2,9)= (1.00 - XSI(K))*(1.00 - ZTA(I))*(81.00*ETA(J)**2 -	BM2	840
1 18.00*ETA(J) - 27.00)	BM2	850
C(2,10)= (1.00 - XSI(K))*(1.00 - ZTA(I))*(27.00 - 18.00*ETA(J) -	BM2	860
1 81.00*ETA(J)**2)	BM2	870
C(2,11)= (1.00 + XSI(K))*(1.00 - ZTA(I))*(81.00*ETA(J)**2 -	BM2	880
1 18.00*ETA(J) - 27.00)	BM2	890
C(2,12)= (1.00 + XSI(K))*(1.00 - ZTA(I))*(27.00 - 18.00*ETA(J) -	BM2	900
1 81.00*ETA(J)**2)	BM2	910
C(2,13)= (1.00 - XSI(K))*(1.00 + ZTA(I))*(81.00*ETA(J)**2 -	BM2	920
1 18.00*ETA(J) - 27.00)	BM2	930
C(2,14)= (1.00 - XSI(K))*(1.00 + ZTA(I))*(27.00 - 18.00*ETA(J) -	BM2	940
1 81.00*ETA(J)**2)	BM2	950
C(2,15)= (1.00 + XSI(K))*(1.00 + ZTA(I))*(81.00*ETA(J)**2 -	BM2	960
1 18.00*ETA(J) - 27.00)	BM2	970
C(2,16)= (1.00 + XSI(K))*(1.00 + ZTA(I))*(27.00 - 18.00*ETA(J) -	BM2	980
1 81.00*ETA(J)**2)	BM2	990
C(2,17)= (1.00 - XSI(K))*(1.00 - ZTA(I))*(27.00*ETA(J)**2 +	BM2	1000
1 9.00*XSI(K)**2 + 18.00*ETA(J) - 10.00)	BM2	1010
C(2,18)= -C(2,2)	BM2	1020


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C(2,19)= -C(2,3) BM2 1030
C(2,20)= (1.00 + XSI(K))*(1.00 - ZTA(I))*(27.00*ETA(J)**2 + BM2 1040
1 9.00*XSI(K)**2 + 18.00*ETA(J) - 10.00) BM2 1050
C(2,21)= (1.00 - XSI(K))*(1.00 + ZTA(I))*(27.00*ETA(J)**2 + BM2 1060
1 9.00*XSI(K)**2 + 18.00*ETA(J) - 10.00) BM2 1070
C(2,22)= (1.00 - 3.00*XSI(K))*(1.00 + ZTA(I))*(9.00-9.00*XSI(K)**2) BM2 1080
C(2,23)= (1.00 + 3.00*XSI(K))*(1.00 + ZTA(I))*(9.00-9.00*XSI(K)**2) BM2 1090
C(2,24)= (1.00 + XSI(K))*(1.00 + ZTA(I))*(27.00*ETA(J)**2 + BM2 1100
1 9.00*XSI(K)**2 + 18.00*ETA(J) - 10.00) BM2 1110
C(3,1) = (1.00 - XSI(K))*(1.00 - ETA(J))*(10.00 - 9.00*XSI(K)**2 BM2 1120
1 -9.00*ETA(J)**2) BM2 1130
C(3,2) = (1.00 -3.00*XSI(K))*(1.00 - ETA(J))*(9.00*XSI(K)**2-9.00) BM2 1140
C(3,3) = (1.00 +3.00*XSI(K))*(1.00 - ETA(J))*(9.00*XSI(K)**2-9.00) BM2 1150
C(3,4) = (1.00 + XSI(K))*(1.00 - ETA(J))*(10.00 - 9.00*XSI(K)**2 BM2 1160
1 -9.00*ETA(J)**2) BM2 1170
DO 26 N=1,4 BM2 1180
26 C(3,N+4) = -C(3,N) BM2 1190
C(3,9) = (1.00 -3.00*ETA(J))*(1.00 - XSI(K))*(9.00*ETA(J)**2-9.00) BM2 1200
C(3,10)= (1.00 +3.00*ETA(J))*(1.00 - XSI(K))*(9.00*ETA(J)**2-9.00) BM2 1210
C(3,11)= (1.00 -3.00*ETA(J))*(1.00 + XSI(K))*(9.00*ETA(J)**2-9.00) BM2 1220
C(3,12)= (1.00 +3.00*ETA(J))*(1.00 + XSI(K))*(9.00*ETA(J)**2-9.00) BM2 1230
DO 27 N=9,12 BM2 1240
27 C(3,N+4) = -C(3,N) BM2 1250
C(3,17)= (1.00 - XSI(K))*(1.00 + ETA(J))*(10.00 - 9.00*XSI(K)**2 BM2 1260
1 -9.00*ETA(J)**2) BM2 1270
C(3,18)= (1.00 -3.00*XSI(K))*(1.00 + ETA(J))*(9.00*XSI(K)**2-9.00) BM2 1280
C(3,19)= (1.00 +3.00*XSI(K))*(1.00 + ETA(J))*(9.00*XSI(K)**2-9.00) BM2 1290
C(3,20)= (1.00 + XSI(K))*(1.00 + ETA(J))*(10.00 - 9.00*XSI(K)**2 BM2 1300
1 -9.00*ETA(J)**2) BM2 1310
DO 28 N=17,20 UM2 1320
28 C(3,N+4) = -C(3,N) BM2 1330
C BM2 1340
C CALCULATE JACOBIAN MATRIX J(3X3) = C(3X24) * XYZ(24X3) AT 32 PT. BM2 1350
C BM2 1360
DO 30 II=1,3 BM2 1370
DO 30 KK=1,3 BM2 1380
DJ(II,KK) = 0.00 BM2 1390
DO 30 JJ=1,24 BM2 1400
30 DJ(II,KK) = DJ(II,KK) + C(II,JJ) * XYZ(JJ,KK) /64.00 BM2 1410
C BM2 1420
C FORM INVERSE J MATRIX DJI(3X3) FOR COORDINATE TRANSFORMATION BM2 1430
C BM2 1440
DETJ = DJ(1,1)*(DJ(2,2)*DJ(3,3) - DJ(2,3)*DJ(3,2)) BM2 1450
1 +DJ(1,2)*(DJ(2,3)*DJ(3,1) - DJ(2,1)*DJ(3,3)) BM2 1460
2 +DJ(1,3)*(DJ(2,2)*DJ(3,1) - DJ(2,2)*DJ(3,2)) BM2 1470
DJI(1,1) = (DJ(2,2)*DJ(3,3) - DJ(2,3)*DJ(3,2)) /DETJ BM2 1480
DJI(1,2) = (DJ(3,2)*DJ(1,3) - DJ(3,3)*DJ(1,2)) /DETJ BM2 1490
DJI(1,3) = (DJ(1,2)*DJ(2,3) - DJ(1,3)*DJ(2,2)) /DETJ BM2 1500
DJI(2,1) = (DJ(2,3)*DJ(3,1) - DJ(2,1)*DJ(3,3)) /DETJ BM2 1510
DJI(2,2) = (DJ(3,3)*DJ(1,1) - DJ(3,1)*DJ(1,3)) /DETJ BM2 1520
DJI(2,3) = (DJ(1,3)*DJ(2,1) - DJ(1,1)*DJ(2,3)) /DETJ BM2 1530

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DJI(3,1) = (DJ(2,1)*DJ(3,2) - DJ(2,2)*DJ(3,1)) /DETJ	BM2 1540
DJI(3,2) = (DJ(3,1)*DJ(1,2) - DJ(3,2)*DJ(1,1)) /DETJ	BM2 1550
DJI(3,3) = (DJ(1,1)*DJ(2,2) - DJ(1,2)*DJ(2,1)) /DETJ	BM2 1560
C FORM MATRIX B(6X72), WHERE (B) = (BA)	BM2 1570
DO 40 N=1,6	BM2 1580
DO 4C L=1,72	BM2 1590
40 BA(N,L) = 0.00	BM2 1600
DO 50 N=1,7C,3	BM2 1610
L = (N - 1)/3 + 1	BM2 1620
BA(1,N) = (DJI(1,1)*C(1,L)+DJI(1,2)*C(2,L)+DJI(1,3)*C(3,L))/64.00	BM2 1630
BA(4,N) = (DJI(2,1)*C(1,L)+DJI(2,2)*C(2,L)+DJI(2,3)*C(3,L))/64.00	BM2 1640
50 BA(5,N) = (DJI(3,1)*C(1,L)+DJI(3,2)*C(2,L)+DJI(3,3)*C(3,L))/64.00	BM2 1650
DO 60 N=2,71,3	BM2 1660
L = (N - 2)/3 + 1	BM2 1670
BA(2,N) = (DJI(2,1)*C(1,L)+DJI(2,2)*C(2,L)+DJI(2,3)*C(3,L))/64.00	BM2 1680
BA(4,N) = (DJI(1,1)*C(1,L)+DJI(1,2)*C(2,L)+DJI(1,3)*C(3,L))/64.00	BM2 1690
60 BA(6,N) = (DJI(3,1)*C(1,L)+DJI(3,2)*C(2,L)+DJI(3,3)*C(3,L))/64.00	BM2 1700
DO 70 N=3,72,3	BM2 1710
L = (N - 3)/3 + 1	BM2 1720
BA(3,N) = (DJI(3,1)*C(1,L)+DJI(3,2)*C(2,L)+DJI(3,3)*C(3,L))/64.00	BM2 1730
BA(5,N) = (DJI(1,1)*C(1,L)+DJI(1,2)*C(2,L)+DJI(1,3)*C(3,L))/64.00	BM2 1740
70 BA(6,N) = (DJI(2,1)*C(1,L)+DJI(2,2)*C(2,L)+DJI(2,3)*C(3,L))/64.00	BM2 1750
RETURN	BM2 1760
END	BM2 1770

	SUBROUTINE SHPFNT	SH2	10
C		SH2	20
C	* * * * *	SH2	30
C	* SUBROUTINE SHPFNT CALCULATES THE SHAPE FUNCTION VECTOR	SH2	40
C	* THIS SUBROUTINE IS CALLED BY -	SH2	50
C	ELSTIF	SH2	60
C	* * * * *	SH2	70
C		SH2	80
C		SH2	90
C		SH2	100
C	IMPLICIT REAL*8 (A-H,O-Z)	SH2	110
	COMMON / STIFIN / D(6,6,24), XNVCT(24), ETM(9), BA(6,72),	SH2	120
1	C(3,24), XYZ(24,3), ALFTMP(6), XSIK, ETAJ, ZTAI	SH2	130
	XP = 1.00 + XSIK	SH2	140
	XM = 1.00 - XSIK	SH2	150
	YP = 1.00 + ETAJ	SH2	160
	YM = 1.00 - ETAJ	SH2	170
	ZP = 1.00 + ZTAI	SH2	180
	ZM = 1.00 - ZTAI	SH2	190
	XP3 = 1.00 + 3.00*XSIK	SH2	200
	XM3 = 1.00 - 3.00*XSIK	SH2	210
	YP3 = 1.00 + 3.00*ETAJ	SH2	220
	YM3 = 1.00 - 3.00*ETAJ	SH2	230
	XNVCT(1) = XM*YM*ZM*(9.00*(XSIK**2+ETAJ**2) - 10.00) / 64.00	SH2	240
	XNVCT(2) = 9.00*XM3*YM*ZM*(1.00-XSIK**2) / 64.00	SH2	250
	XNVCT(3) = XNVCT(2) * XP3 / XM3	SH2	260
	XNVCT(4) = XNVCT(1) * XP / XM	SH2	270
	XNVCT(5) = XNVCT(1) * ZP / ZM	SH2	280
	XNVCT(6) = XNVCT(2) * ZP / ZM	SH2	290
	XNVCT(7) = XNVCT(3) * ZP / ZM	SH2	300
	XNVCT(8) = XNVCT(4) * ZP / ZM	SH2	310
	XNVCT(9) = 9.00 * XM*YM3*ZM*(1.00-ETAJ**2) / 64.00	SH2	320
	XNVCT(10) = XNVCT(9) * YP3 / YM3	SH2	330
	XNVCT(11) = XNVCT(9) * XP / XM	SH2	340
	XNVCT(12) = XNVCT(11) * YP3 / YM3	SH2	350
	XNVCT(13) = XNVCT(9) * ZP / ZM	SH2	360
	XNVCT(14) = XNVCT(13) * YP3 / YM3	SH2	370
	XNVCT(15) = XNVCT(13) * XP / XM	SH2	380
	XNVCT(16) = XNVCT(14) * XP / XM	SH2	390
	XNVCT(17) = XNVCT(1) * YP / YM	SH2	400
	XNVCT(18) = XNVCT(2) * YP / YM	SH2	410
	XNVCT(19) = XNVCT(18) * XP3 / XM3	SH2	420
	XNVCT(20) = XNVCT(17) * XP / XM	SH2	430
	XNVCT(21) = XNVCT(17) * ZP / ZM	SH2	440
	XNVCT(22) = XNVCT(18) * ZP / ZM	SH2	450
	XNVCT(23) = XNVCT(22) * XP3 / XM3	SH2	460
	XNVCT(24) = XNVCT(21) * XP / XM	SH2	470
	RETURN	SH2	480
	END	SH2	490
		SH2	500

	SUBROUTINE DMAT	DM2	10
C		DM2	20
C	* * * * *	DM2	30
C	* * * * *	DM2	40
C	* SUBROUTINE DMAT CALCULATES THE ELASTIC MATRIX AND PERFORMS A	DM2	50
C	* ROTATIONAL TRANSFORMATION ON THE ELASTIC MATRIX	DM2	60
C	* * * * *	DM2	70
C	* THIS SUBROUTINE IS CALLED BY -	DM2	80
C	* ELAS	DM2	90
C	* * * * *	DM2	100
C	* * * * *	DM2	110
C		DM2	120
	IMPLICIT REAL*8.(A-H,O-Z)	DM2	130
	INTEGER*2 IX, ICODE, GNMAT, MTLND, LDBC	D'	140
	COMMON / GENL / XINIT, EPS, AMBTMP,	DM2	150
	1 ICLASS, NEL, NGNP, NGLDF, NMTL, NTYEL, LIMIT, NM, NDBC	DM2	160
	COMMON / NODELM/ X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	DM2	170
	1 UZ(1015), TMPND(1015), FBC(3045), DBC(3045), TBC(1,72),	DM2	180
	2 ICODE(1015), IX(144,27), GNMAT(144,72), MTLND(1015), LDBC(1015)	DM2	190
	COMMON / MATL / E(9,9,10), FIBORT(9), ALFA1(9),	DM2	200
	1 ALFA2(9), ALFA3(9), TMPEL(9,10), NTMP(9)	DM2	210
	COMMON / STIFIN / D(6,6,24), XNVCT(24), ETM(9), BA(6,72),	DM2	220
	1 C(3,24), XYZ(24,3), ALFTMP(6), XSIK, ETAJ, ZTAI	DM2	230
	COMMON / INDX / INEL, IGNP, ILNP, IMTL	DM2	240
	DIMENSION T(6,6), TD(6,6), TT(6,6), TMPCOF(6), DTMP(6,6)	DM2	250
	DO 10 I=1,6	DM2	260
	DO 10 J=1,6	DM2	270
	T(I,J) = 0.00	DM2	280
	D(I,J,ILNP) = 0.00	DM2	290
10	TD(I,J) = 0.00	DM2	300
	XNU21 = ETM(4) * ETM(2) / ETM(1)	DM2	310
	XNU31 = ETM(5) * ETM(3) / ETM(1)	DM2	320
	XNU32 = ETM(6) * ETM(3) / ETM(2)	DM2	330
	FACT=1.00-ETM(4)*(XNU21+ETM(6)*XNU31)-ETM(5)*(XNU31+XNU32*XNU21)-	DM2	340
1	ETM(6)*XNU32	DM2	350
	D(1,1,ILNP)= ETM(1) * (1.00 - ETM(6) * XNU32) / FACT	DM2	360
	D(1,2,ILNP) = ETM(2) * (ETM(4) + ETM(5) * XNU32) / FACT	DM2	370
	D(1,3,ILNP) = ETM(3) * (ETM(5) + ETM(4) * ETM(6)) / FACT	DM2	380
	D(2,1,ILNP) = D(1,2,ILNP)	DM2	390
	D(2,2,ILNP) = ETM(2) * (1.00 - ETM(5) * XNU31) / FACT	DM2	400
	D(2,3,ILNP) = ETM(3) * (ETM(6) + ETM(5) * XNU21) / FACT	DM2	410
	D(3,1,ILNP) = D(1,3,ILNP)	DM2	420
	D(3,2,ILNP) = D(2,3,ILNP)	DM2	430
	D(3,3,ILNP) = ETM(3) * (1.00 - ETM(4) * XNU21) / FACT	DM2	440
	D(4,4,ILNP) = ETM(7)	DM2	450
	D(5,5,ILNP) = ETM(8)	DM2	460
	D(6,6,ILNP) = ETM(9)	DM2	470
	ALFTMP(1) = ALFA1(IMTL)	DM2	480
	ALFTMP(2) = ALFA2(IMTL)	DM2	490
	ALFTMP(3) = ALFA3(IMTL)	DM2	500
	DO 60 I=4,6	DM2	510

60 ALFTMP(I) = 000	DM2 520
IF(DABS(FIBORT(IMTL)) .LT. .5D-14) GO TO 50	DM2 530
FIBOR = FIBORT(IMTL) * 3.141592653589793200 / 180.00	DM2 540
T(1,1) = DCOS(FIBOR)**2	DM2 550
T(1,2) = DSIN(FIBOR)**2	DM2 560
T(4,1) = DCOS(FIBOR) * DSIN(FIBOR)	DM2 570
T(1,4) = -2.00 * T(4,1)	DM2 580
T(2,1) = T(1,2)	DM2 590
T(2,2) = T(1,1)	DM2 600
T(2,4) = -T(1,4)	DM2 610
T(3,3) = 1.00	DM2 620
T(4,2) = -T(4,1)	DM2 630
T(4,4) = T(1,1) - T(1,2)	DM2 640
T(5,5) = DCOS(FIBOR)	DM2 650
T(6,5) = DSIN(FIBOR)	DM2 660
T(5,6) = -T(6,5)	DM2 670
T(6,6) = T(5,5)	DM2 680
DO 70 I=1,6	DM2 690
TMPCOF(I) = 000	DM2 700
DO 70 J=1,6	DM2 710
70 TMPCOF(I) = TMPCOF(I) + T(I,J) * ALFTMP(J)	DM2 720
DO 90 I=1,6	DM2 730
90 ALFTMP(I) = TMPCOF(I)	DM2 740
DO 20 I=1,6	DM2 750
DO 20 J=1,6	DM2 760
DO 20 K=1,6	DM2 770
20 TD(I,J) = TD(I,J) + T(I,K)*D(K,J,ILNP)	DM2 780
DO 80 I=1,6	DM2 790
DO 80 J=1,6	DM2 800
80 TT(J,I) = T(I,J)	DM2 810
DO 30 I=1,6	DM2 820
DO 30 J=1,6	DM2 830
DTMP(I,J) = 000	DM2 840
DO 30 K=1,6	DM2 850
30 DTMP(I,J) = DTMP(I,J) + TD(I,K) * TT(K,J)	DM2 860
DO 40 I=1,6	DM2 870
DO 40 J=1,6	DM2 880
40 D(I,J,ILNP) = DTMP(I,J)	DM2 890
50 CONTINUE	DM2 900
RETURN	DM2 910
END	DM2 920

	SUBROUTINE	FBCDBC	FB2	10
C			FB2	20
C	*****		FB2	30
C			FB2	40
C	* SUBROUTINE FBCDBC FORMS A FORCE AND A DISPLACEMENT ARRAY		FB2	50
C			FB2	60
C	* THIS SUBROUTINE IS CALLED BY -		FB2	70
C		MAIN	FB2	80
C			FB2	90
C	*****		FB2	100
C			FB2	110
	IMPLICIT REAL*8 (A-H,O-Z)		FB2	120
	INTEGER*2 IX, ICODE, GNMAT, MTLND, LDBC		FB2	130
	COMMON / GENL / XINIT, EPS, AMBTMP,		FB2	140
	1 ICLASS, NEL, NGNP, NGLDF, NMTL, NTYEL, LIMIT, NM, NDBC		FB2	150
	COMMON /NODELM/ X(1015), Y(1015), Z(1015), UX(1015), UY(1015),		FB2	160
	1 UZ(1015), TMPND(1015), FBC(3045), DBC(3045), TBC(1,72),		FB2	170
	2 ICODE(1015), IX(144,27), GNMAT(144,72),MTLND(1015),LDBC(1015)		FB2	180
	COMMON /MATL / E(9,9,10), FIBORT(9), ALFA1(9),		FB2	190
	1 ALFA2(9), ALFA3(9), IMPEL(9,10), NTMP(9)		FB2	200
	IDBC = 0		FB2	210
	DO 7 I=1,NGNP		FB2	220
	IF(ICODE(I) .EQ. 1 .OR. ICODE(I) .EQ. 3) GO TO 2		FB2	230
	IF(ICODE(I) .EQ. 2) GO TO 3		FB2	240
	IF(ICODE(I) .EQ. 7) GO TO 4		FB2	250
	FBC(3*I-2) = UX(I)		FB2	260
	IF(ICODE(I) .EQ. 4) GO TO 3		FB2	270
	IF(ICODE(I) .EQ. 6) GO TO 5		FB2	280
	2 FBC(3*I-1) = UY(I)		FB2	290
	IF(ICODE(I) .EQ. 3) GO TO 4		FB2	300
	IF(ICODE(I) .EQ. 5) GO TO 6		FB2	310
	3 FBC(3*I) = UZ(I)		FB2	320
	IF(ICODE(I) .EQ. 0) GO TO 7		FB2	330
	IF(ICODE(I) .EQ. 4) GO TO 5		FB2	340
	4 IDBC = IDBC + 1		FB2	350
	LDBC(IDBC) = 3*I-2		FB2	360
	DBC(3*I-2) = UX (I)		FB2	370
	IF(ICODE(I) .EQ. 1) GO TO 7		FB2	380
	IF(ICODE(I) .EQ. 3) GO TO 6		FB2	390
	5 IDBC = IDBC + 1		FB2	400
	LDBC(IDBC) = 3*I-1		FB2	410
	DBC(3*I-1) = UY (I)		FB2	420
	IF(ICODE(I) .EQ. 2 .OR. ICODE(I) .EQ. 4) GO TO 7		FB2	430
	6 IDBC = IDBC + 1		FB2	440
	LDBC(IDBC) = 3*I		FB2	450
	DBC(3*I) = UZ (I)		FB2	460
	7 CONTINUE		FB2	470
	NDBC = IDBC		FB2	480
	RETURN		FB2	490
	END		FB2	500

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C MAIN PROGRAM STEP 3 (ITERATION IN CORE VERSION)          ESC 10
C                                                         ESC 20
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * ESC 30
C *                                                         ESC 40
C * STEP 3 PERFORMS FIVE FUNCTIONS                          ESC 50
C *                                                         ESC 60
C * 1.  COMBINES NON-ZERO DISPLACEMENT BOUNDARY CONDITIONS WITH ESC 70
C *      THE FORCE VECTOR .                                  ESC 80
C *                                                         ESC 90
C * 2.  SOLVES THE SYSTEM OF LINEAR EQUATIONS BY MINIMIZING THE ESC 100
C *      TOTAL POTENTIAL ENERGY                           ESC 110
C *                                                         ESC 120
C * 3.  CALCULATES AND PRINTS THE STRAIN ENERGY AND OTHER ESC 130
C *      CONVERGENCE PARAMETERS                             ESC 140
C *                                                         ESC 150
C * 4.  PRINTS THE COORDINATE AND THREE (X,Y,&Z) DISPLACEMENTS ESC 160
C *      AT EACH NODE                                       ESC 170
C *                                                         ESC 180
C * 5.  WRITES DISPLACEMENTS ON DISK AND/OR CARDS          ESC 190
C *                                                         ESC 200
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * ESC 210
C *                                                         ESC 220
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * ESC 230
C *                                                         ESC 240
C * VARIABLE DEFINITIONS AND DIMENSIONS FOR STEP 3         ESC 250
C *                                                         ESC 260
C * ACB - - - - - CHANGE IN STRAIN ENERGY OVER STRAIN ENERGY ESC 270
C *                                                         ESC 280
C * D(INGLDF) - - - - - FORCE VECTOR                        ESC 290
C *                                                         ESC 300
C * BNRM - - - - - MAGNITUDE OF THE FORCE VECTOR           ESC 310
C *                                                         ESC 320
C * DBC(MM) - - - - - NON-ZERO DISPLACEMENT BOUNDARY CONDITIONS ESC 330
C *                                                         ESC 340
C * DELE - - - - - CHANGE IN STRAIN ENERGY                ESC 350
C *                                                         ESC 360
C * DELXNR - - - - - MAGNITUDE OF THE CHANGE IN DISPLACEMENT ESC 370
C *                   VECTOR                                ESC 380
C *                                                         ESC 390
C * ENGY1 - - - - - STRAIN ENERGY                         ESC 400
C *                                                         ESC 410
C * FNGY2 - - - - - STRAIN ENERGY                         ESC 420
C *                                                         ESC 430
C * EPS - - - - - ENERGY CONVERGENCE TEST PARAMETER      ESC 440
C *                                                         ESC 450
C * G(INGLDF) - - - - - RESULTING VECTOR FROM KX OR KP MATRIX- ESC 460
C *                   VECTOR PRODUCT                       ESC 470
C *                                                         ESC 480
C * GNMAT(NEL,72) - - RELATES LOCAL AND GLOBAL DEGREES-OF-FREEDOM ESC 490
C *                                                         ESC 500
C * IX26(NEL) - - - - ELEMENT TYPE FOR EACH ELEMENT       ESC 510

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C	*		* ESC	520
C	*	KEMAT(NTYEL,2628)- MATRIX OF THE UPPER SYMMETRIC PORTION OF THE	* ESC	530
C	*	UNIQUE ELEMENT STIFFNESS MATRICES - EACH	* ESC	540
C	*	ELEMENT STIFFNESS MATRIX IS STORED AS A ROW	* ESC	550
C	*	IN KEMAT	* ESC	560
C	*		* ESC	570
C	*	KOUNT - - - - - TOTAL NUMBER OF ITERATIONS	* ESC	580
C	*		* ESC	590
C	*	LDBC(NDBC) - - - - INDEX FOR DISPLACEMENT BOUNDARY CONDITIONS	* ESC	600
C	*		* ESC	610
C	*	LLDBC(MM) - - - - INDEX NUMBERS FOR NON-ZERO DISPLACEMENT	* ESC	620
C	*	BOUNDARY CONDITIONS	* ESC	630
C	*		* ESC	640
C	*	MM - - - - - NUMBER OF NON-ZERO DISPLACEMENT BOUNDARY	* ESC	650
C	*	CONDITIONS	* ESC	660
C	*		* ESC	670
C	*	NDBC - - - - - NUMBER OF DISPLACEMENT BOUNDARY CONDITIONS	* ESC	680
C	*		* ESC	690
C	*	NEL - - - - - NUMBER OF ELEMENTS	* ESC	700
C	*		* ESC	710
C	*	NGLDF - - - - - NUMBER OF DEGREES-OF-FREEDOM (GLOBAL SYSTEM)	* ESC	720
C	*		* ESC	730
C	*	NTYEL - - - - - NUMBER OF UNIQUE ELEMENTS	* ESC	740
C	*		* ESC	750
C	*	P(NGLDF) - - - - - CORRECTION VECTOR IN CONJUGATE GRADIENT	* ESC	760
C	*	ROUTINE	* ESC	770
C	*		* ESC	780
C	*	R(NGLDF) - - - - - RESIDUE VECTOR IN CONJUGATE GRADIENT	* ESC	790
C	*	ROUTINE	* ESC	800
C	*		* ESC	810
C	*	RNRM - - - - - MAGNITUDE OF THE RESIDUE VECTOR	* ESC	820
C	*		* ESC	830
C	*	UX(NGNP) - - - - - DISPLACEMENTS IN THE X-DIRECTION	* ESC	840
C	*		* ESC	850
C	*	UY(NGNP) - - - - - DISPLACEMENTS IN THE Y-DIRECTION	* ESC	860
C	*		* ESC	870
C	*	UZ(NGNP) - - - - - DISPLACEMENTS IN THE Z-DIRECTION	* ESC	880
C	*		* ESC	890
C	*	X(NGLDF) - - - - - DISPLACEMENT VECTOR	* ESC	900
C	*		* ESC	910
C	*	XCORD(NGNP) - - - X-COORDINATE (GLOBAL SYSTEM)	* ESC	920
C	*		* ESC	930
C	*	YCORD(NGNP) - - - Y-COORDINATE (GLOBAL SYSTEM)	* ESC	940
C	*		* ESC	950
C	*	ZCORD(NGNP) - - - Z-COORDINATE (GLOBAL SYSTEM)	* ESC	960
C	*		* ESC	970
C	*	*****	* ESC	980
C	*		* ESC	990
C	*	*****	* ESC	1000
C	*		* ESC	1010
C	*	LOGICAL SWITCH INFORMATION (ALL SWITCHES INITIALLY FALSE.)	* ESC	1020


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102 FORMAT(5216) ESC 1540
201 FORMAT('OMAXIMUM NUMBER OF ITERATIONS FOR THIS RUN IS' , 15) ESC 1550
301 FORMAT('ODELTA STRAIN ENERGY / STRAIN ENERGY DID CONVERGE TO ' ESC 1560
1 , E14.7, ' AFTER' , 16, ' ITERATIONS AND ACCURATE TO',E14.7) ESC 1570
302 FORMAT('TIME IN CG SUBROUTINE IS ' , F7.2, ' SECONDS') ESC 1580
303 FORMAT('ODELTA STRAIN ENERGY / STRAIN ENERGY DID NOT CONVERGE TO 'ESC 1590
1 , E14.7, ' AFTER' , 16, ' ITERATIONS BUT ACCURATE TO',E14.7) ESC 1600
304 FORMAT('O', G14.7, ' IS THE INITIAL GUESS FOR ALL DISPLACEMENTS') ESC 1610
305 FORMAT ('O THE INITIAL GUESSES FOR DISPLACEMENTS ARE READ FROM CARDESC 1620
1S AND MULTIPLIED BY A FACTOR OF' , G14.7) ESC 1630
306 FORMAT ('O THE INITIAL GUESSES FOR DISPLACEMENTS ARE READ FROM CARDESC 1640
1S AND THE Z-DISPLACEMENTS ARE MULTIPLIED BY A FACTOR OF' , G14.7) ESC 1650
307 FORMAT('O THE INITIAL GUESSES FOR DISPLACEMENTS ARE READ FROM DISK' ESC 1660
1 ) ESC 1670
308 FORMAT('OSTRAIN ENERGY', T50, E14.7 , ' K IN-LBS' / ESC 1680
1 ' CHANGE IN STRAIN ENERGY', T50, E14.7 , ' K IN-LBS' / ESC 1690
2 ' MAGNITUDE OF THE RESIDUE VECTOR', T50, E14.7 , ' K LBS' / ESC 1700
3 ' MAGNITUDE OF THE FORCE VECTOR', T50, E14.7 , ' K LBS' / ESC 1710
4 ' MAGNITUDE OF THE CHANGE IN DISPLACEMENT VECTOR', T50, E14.7 ESC 1720
5, ' IN' / ' MAGNITUDE OF THE DISPLACEMENT VECTOR', T50, E14.7, ' IN' ESC 1730
2000 FORMAT('O', 7X, 'NODE', 13X, 'X-COORD', 13X, 'Y-COORD', 13X, 'Z-COORD', ESC 1740
1 9X, 'X-DISPL', 13X, 'Y-DISPL', 13X, 'Z-DISPL' / ESC 1750
2 27X, 'INS', 17X, 'INS', 17X, 'INS', 13X, 'INS', 17X, 'INS', ESC 1760
3 17X, 'INS' / ) ESC 1770
2001 FORMAT(6X, 15, 3F20.5, 3E20.7) ESC 1780
DEFINE FILE 3(55,6500,U,IDXDA) ESC 1790
IUDA = 3 ESC 1800
LIST = 6 ESC 1810
C ESC 1820
C READ CARD DATA FOR STEP 3 ESC 1830
C ESC 1840
READ(5,100) INTXMD, ITRLMT, FACTOR, EPS, IOSPL ESC 1850
WRITE(LIST,201) ITRLMT ESC 1860
C ESC 1870
C READ DATA GENERATED IN STEP 2 ESC 1880
C ESC 1890
READ (IUDA*1) NEL, NGLDF, NDBC, NTYEL, LIMIT, NGNP, NMTL, ESC 1900
1 HED, IPAGE, AMBTMP ESC 1910
READ (IUDA*4) ( B(J), J=1, NGLDF) ESC 1920
1 SW, NUCNV, (LDBC(J), J=1, NDBC) ESC 1930
READ (IUDA*5) ( P(J), J=1, NGLDF) ESC 1940
1 , (IX26(J), J=1, NEL) ESC 1950
READ (IUDA*6) ((GNMAT(I,J), J=1, 72), I=1, NEL) ESC 1960
C ESC 1970
C READ UNIQUE ELEMENT STIFFNESS MATRICES ESC 1980
C ESC 1990
DO 44 I=1, NTYEL ESC 2000
44 READ(IUDA*IDXDA) (KEMAT(I,J), J=1, 2628) ESC 2010
IDXDA = NTYEL+7 ESC 2020
C ESC 2030
C DETERMINE INITIAL GUESS FOR THE DISPLACEMENT VECTOR ESC 2040

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GO TO (21,22,23,24), INTXMD	ESC 2050
21 DO 50 I=1,NGLDF	ESC 2060
50 X(I) = FACTOR	ESC 2070
WRITE(LIST,304) FACTOR	ESC 2080
GO TO 27	ESC 2090
22 READ(5,102) (X(J),J=1,NGLDF)	ESC 2100
DO 61 I=1,NGLDF	ESC 2110
61 X(I) = FACTOR*X(I)	ESC 2120
WRITE(LIST,305) FACTOR	ESC 2130
GO TO 29	ESC 2140
23 READ(5,102) (X(J),J=1,NGLDF)	ESC 2150
DO 10 I=1,NGNP	ESC 2160
10 X(3*I) = FACTOR*X(3*I)	ESC 2170
WRITE(LIST,306) FACTOR	ESC 2180
GO TO 29	ESC 2190
24 READ (IUDA*IDXDA)SW,MM, (DBC(J),J=1,MM), (LLDBC(J),J=1,MM), KOUNT,	ESC 2200
I' (X(J),J=1,NGLDF)	ESC 2210
SW(8) = .TRUE.	ESC 2220
SW(3) = .FALSE.	ESC 2230
35 IF(.NOT. SW(10)) GO TO 33	ESC 2240
MM = 0	ESC 2250
33 READ (IUDA*IDXDA) (B(J),J=1,NGLDF)	ESC 2260
WRITE(LIST,307)	ESC 2270
GO TO 34	ESC 2280
29 CONTINUE	ESC 2290
C	ESC 2300
C CONVLRIT INITIAL DISPLACEMENT BOUNDARY CONDITIONS TO FORCE BOUNDARY	ESC 2310
C CONDITIONS	ESC 2320
C	ESC 2330
MM = 0	ESC 2340
DO 60 I=1,NGLDF	ESC 2350
IF(DABS(P(I)) .LT. 1.0-14) GO TO 60	ESC 2360
MM = MM + 1	ESC 2370
DBC(MM) = P(I)	ESC 2380
LLDBC(MM) = 1	ESC 2390
60 CONTINUE	ESC 2400
DO 13 I=1,NGLDF	ESC 2410
13 G(I) = 0.00	ESC 2420
DO 15 INEL=1,NEL	ESC 2430
ITEL = IX26(INEL)	ESC 2440
15 CALL GVT(GNMAT, KEMAT, G, P, INLL, ITEL)	ESC 2450
DO 80 I=1,NGLDF	ESC 2460
80 B(I) = B(I) - G(I)	ESC 2470
34 CALL TIMON	ESC 2480
C	ESC 2490
C MINIMIZE TOTAL POTENTIAL ENERGY	ESC 2500
C	ESC 2510
CALL CGJRD	ESC 2520
CALL TIMECK(ITIME)	ESC 2530
SEC = ITIME/100.	ESC 2540
	ESC 2550

C		ESC 2560
C	WRITE FORCE AND DISPLACEMENT DATA ON DISK FOR USE IN FUTURE RUNS	ESC 2570
C		ESC 2580
	IF(MM .NE. 0) GO TO 31	ESC 2590
	SW(1) = .TRUE.	ESC 2600
	MM = 1	ESC 2610
	DBC(1) = 000	ESC 2620
31	IDXDA = NTYLL + 7	ESC 2630
	WRITE(IUDA>IDXDA)SW,MM, (DBC(J),J=1,MM), (LLDBC(J),J=1,MM), KOUNT,	ESC 2640
1	(X(J),J=1,NGLOF)	ESC 2650
	WRITE(IUDA>IDXDA) (B(J),J=1,NGLOF)	ESC 2660
C		ESC 2670
C	PRINT STRAIN ENERGY AND CONVERGENCE DATA	ESC 2680
C		ESC 2690
	IF(SW(1)) GO TO 20	ESC 2700
	WRITE(LIST,303) EPS, KOUNT, ACB	ESC 2710
	GO TO 9	ESC 2720
20	WRITE(LIST,301) EPS, KOUNT, ACB	ESC 2730
9	WRITE(LIST,302) SEC	ESC 2740
	WRITE(LIST,308) ENGY1, DELE, RNRM, BNRM, DELXNR, XNRM	ESC 2750
	IF(IDSPL .EQ. 0) GO TO 32	ESC 2760
C		ESC 2770
C	PRINT AND/OR PUNCH THE DISPLACEMENT VECTOR	ESC 2780
C		ESC 2790
C		ESC 2800
	IF(IDSPL .EQ. 2) GO TO 43	ESC 2810
	READ(IUDA*3)(XCORD(J),J=1,NGNP), (YCORD(J),J=1,NGNP),	ESC 2820
1	(ZCORD(J),J=1,NGNP)	ESC 2830
	CALL TITLE	ESC 2840
	WRITE(LIST,2000)	ESC 2850
	DO 30 I=1,NGNP	ESC 2860
	IF(LINE .LT. 48) GO TO 94	ESC 2870
	CALL TITLE	ESC 2880
	WRITE(LIST,2000)	ESC 2890
94	CONTINUE	ESC 2900
	LINE = LINE + 1	ESC 2910
	UX(I) = X(3*I-2)	ESC 2920
	UY(I) = X(3*I-1)	ESC 2930
	UZ(I) = X(3*I)	ESC 2940
30	WRITE(LIST,2001) I, XCORD(I), YCORD(I), ZCORD(I),	ESC 2950
1	UX(I), UY(I), UZ(I)	ESC 2960
	IF(IDSPL .EQ. 1) GO TO 32	ESC 2970
43	WRITE(7,102) (X(I),I=1,NGLOF)	ESC 2980
32	STOP	ESC 2990
	END	ESC 3000

	SUBROUTINE CGJRD	CGC 10
C		CGC 20
C	*****	CGC 30
C	*	CGC 40
C	* SUBROUTINE CGJRD MINIMIZES THE TOTAL POTENTIAL ENERGY BY THE	CGC 50
C	* CONJUGATE GRADIENT METHOD AND TESTS THE STRAIN ENERGY FOR	CGC 60
C	* CONVERGENCE	CGC 70
C	*	CGC 80
C	* THIS SUBROUTINE IS CALLED BY -	CGC 90
C	* MAIN	CGC 100
C	*	CGC 110
C	* THIS SUBROUTINE CALLS	CGC 120
C	* GVT	CGC 130
C	*	CGC 140
C	*****	CGC 150
C		CGC 160
C		CGC 170
C	IMPLICIT REAL*8 (A-H,O-Z)	CGC 180
	REAL*8 KEMAT	CGC 190
	INTEGER*2 GNMAT, LDBC, LLDBC, IX26	CGC 200
	LOGICAL*1 SW	CGC 210
	COMMON / KEGN / KEMAT(3,2628), GNMAT(64,72), IX26(65)	CGC 220
	COMMON / CGVECT / G(1575), X(1575), B(1575), P(1575), R(1575)	CGC 230
	COMMON / SCALAR / EPS, ACB, XNRM, BNRN, RNRN, DELXNR,	CGC 240
	1 DELF, ENGY1, ENGY2,	CGC 250
	2 NGLDF, LIMIT, NEL, KOUNT, ITEL, ITRLMT, MM	CGC 260
	COMMON / BC / UBC(200), LLDBC(200), LDBC(700), NDBC	CGC 270
	COMMON / SWITCH / SW(12)	CGC 280
	ITKNT = 0	CGC 290
	IF(SW(8)) GO TO 2	CGC 300
	KOUNT = 0	CGC 310
	BETA = 0.00	CGC 320
C		CGC 330
C	RESTART ITERATIVE PROCESS BY FINDING NEW RESIDUE VECTOR	CGC 340
C		CGC 350
	2 DO 10 I = 1, NGLDF	CGC 360
	10 G(I) = 0.00	CGC 370
	DO 70 I = 1, NDBC	CGC 380
	B(LDBC(I)) = 0.00	CGC 390
	70 X(LDBC(I)) = 0.00	CGC 400
	DO 31 INFL = 1, NEL	CGC 410
	ITEL = IX26(INEL)	CGC 420
	31 CALL GVT(GNMAT, KEMAT, G, X, INEL, ITEL)	CGC 430
	DO 32 I = 1, NDBC	CGC 440
	32 G(LDBC(I)) = 0.00	CGC 450
	RNRM1 = 0.00	CGC 460
	DO 20 I = 1, NGLDF	CGC 470
	P(I) = B(I) - G(I)	CGC 480
	R(I) = P(I)	CGC 490
	20 RNRM1 = RNRM1 + R(I) * R(I)	CGC 500
C		CGC 510

C	CALCULATE STRAIN ENERGY	CGC	520
C		CGC	530
	IF(.NOT. (SW(3) .OR. SW(4))) GO TO 5	CGC	540
	IF(MM .EQ. 0) GO TO 95	CGC	550
	DO 9C I=1,MM	CGC	560
	90 X(LLDBC(I)) = DBC(I)	CGC	570
	95 ENGY1 = 0.00	CGC	580
	DO 17 I=1,NGLDF	CGC	590
	17 G(I) = 0.00	CGC	600
	DO 34 INEL=1,NEL	CGC	610
	ITEL = IX26(INEL)	CGC	620
	34 CALL GVT(GNMAT, KEMAT, G, X, INEL, ITEL)	CGC	630
	DO 92 I=1,NGLDF	CGC	640
	92 ENGY1 = ENGY1 + X(I) * G(I)	CGC	650
	ENGY1 = .500 * ENGY1	CGC	660
	ENGY2 = ENGY1	CGC	670
C		CGC	680
C	FIND ALFA	CGC	690
C		CGC	700
	5 DO 35 I=1,NGLDF	CGC	710
	35 G(I) = 0.00	CGC	720
	DO 33 INEL=1,NEL	CGC	730
	ITEL = IX26(INEL)	CGC	740
	33 CALL GVT(GNMAT, KEMAT, G, P, INEL, ITEL)	CGC	750
	DO 36 I=1,NDBC	CGC	760
	36 G(LLDBC(I)) = 0.00	CGC	770
	PKP = 0.00	CGC	780
	DO 30 I = 1,NGLDF	CGC	790
	30 PKP = PKP + P(I) * G(I)	CGC	800
	ALFA = RNRM1 / PKP	CGC	810
	IF(SW(3)) GO TO 25	CGC	820
C		CGC	830
C	CORRECT THE DISPLACEMENT VECTOR	CGC	840
C		CGC	850
	DO 40 I = 1,NGLDF	CGC	860
	40 X(I) = X(I) + ALFA * P(I)	CGC	870
	ITKNT = ITKNT + 1	CGC	880
	KOUNT = KOUNT + 1	CGC	890
	IF(ITKNT .LT. ITRLMT) GO TO 7	CGC	900
	SW(3) = .TRUE.	CGC	910
	GO TO 2	CGC	920
	7 IF(SW(4)) GO TO 12	CGC	930
	IF (RNRM1 .GT. 1.) GO TO 11	CGC	940
	SW(4) = .TRUE.	CGC	950
	GO TO 2	CGC	960
	11 RNRM2 = 0.00	CGC	970
C		CGC	980
C	FIND NEW RESIDUE VECTOR AND NEW P VECTOR	CGC	990
C		CGC	1000
	DO 50 I = 1,NGLDF	CGC	1010
	R(I) = R(I) - ALFA*G(I)	CGC	1020

50 RNRM2 = RNRM2 + R(I) * R(I)	CGC 1030
BETA = RNRM2/RNRM1	CGC 1040
DO 60 I = 1,NGLDF	CGC 1050
60 P(I) = R(I) + BETA * P(I)	CGC 1060
RNRM1 = RNRM2	CGC 1070
GO TO 5	CGC 1080
C	CGC 1090
C FIND CHANGE IN STRAIN ENERGY FROM ALFA & RNRM1	CGC 1100
C	CGC 1110
12 DELE = .500 * ALFA * RNRM1	CGC 1120
ENG2 = ENG2 - DELE	CGC 1130
IF(DFLE/ENG2 .LT. EPS) GO TO 14	CGC 1140
SW(2) = .FALSE.	CGC 1150
GO TO 11	CGC 1160
14 IF(SW(2)) GO TO 15	CGC 1170
SW(2) = .TRUE.	CGC 1180
GO TO 2	CGC 1190
15 SW(1) = .TRUE.	CGC 1200
C	CGC 1210
C CALCULATE CONVERGENCE PARAMETERS	CGC 1220
C	CGC 1230
25 XNRM = 0.00	CGC 1240
BNRM = 0.00	CGC 1250
DELXNR = 0.00	CGC 1260
DO 16 I=1,NGLDF	CGC 1270
XNRM = XNRM + X(I) * X(I)	CGC 1280
BNRM = BNRM + b(I) * b(I)	CGC 1290
16 DELXNR = DELXNR + P(I) * P(I)	CGC 1300
XNRM = DSORT(XNRM)	CGC 1310
BNRM = DSORT(BNRM)	CGC 1320
RNRM = DSORT(RNRM1)	CGC 1330
DELXNR = ALFA * DSORT(DELXNR)	CGC 1340
IF(.NOT. SW(2)) DELE = .500 * ALFA * RNRM1	CGC 1350
ACB = DELE / ENG2	CGC 1360
RETURN	CGC 1370
END	CGC 1380

	SUBROUTINE TITLE	TIC	10
C		TIC	20
C	* * * * *	TIC	30
C	*	TIC	40
C	* SUBROUTINE TITLE PRINTS THE HEADING ON EACH PAGE	TIC	50
C	* THIS SUBROUTINE IS CALLED BY -	TIC	60
C	* MAIN	TIC	70
C	*	TIC	80
C	* * * * *	TIC	90
C		TIC	100
	IMPLICIT REAL*8 (A-H,O-Z)	TIC	110
	COMMON / HEAD / HED(10),ICRD,LIST,IPAGE,LINE	TIC	120
100	FORMAT (1H1,'FEM 72-DOF GENERAL HEXAHEDRONS THERMO-ELASTIC, VARYINTIC	TIC	130
	1G MATERIAL PROPERTIES, DANA', 9X, 'PAGE', 13)	TIC	140
101	FORMAT (1H0,10A8)	TIC	150
	LIST = 6	TIC	160
	IWRT = 6	TIC	170
	WRITE (LIST,103) IPAGE	TIC	180
	WRITE (LIST,101) HED	TIC	190
	IPAGE= IPAGE +1	TIC	200
	LINE = 0	TIC	210
	RETURN	TIC	220
	END	TIC	230

C	SUBROUTINE GVT(GNMAT,KEMAT,G,P,INEL, ITEL)	GVC	10
C		GVC	20
C	* * * * *	GVC	30
C	* SUBROUTINE GVT FORMS THE MATRIX-VECTOR PRODUCT KP=G WHERE K	GVC	40
C	* REPRESENTS THE NON-FORMED GLOBAL STIFFNESS MATRIX	GVC	50
C	* THIS SUBROUTINE IS CALLED BY -	GVC	60
C	* MAIN	GVC	70
C	* CGJRD	GVC	80
C	* NOTE: OVER 90 PERCENT OF THE TIME IN STEP 3 IS SPENT IN THIS	GVC	90
C	* SUBROUTINE - IT IS RECOMMEND THAT THIS SUBROUTINE BE REWRITTEN	GVC	100
C	* IN ASSEMBLY LANGUAGE TO OPTIMIZE THE CODE.	GVC	110
C	* * * * *	GVC	120
C		GVC	130
C		GVC	140
C		GVC	150
C		GVC	160
C		GVC	170
	REAL*8 KEMAT, G , P	GVC	180
	INTEGER*2 GNMAT	GVC	190
	DIMENSION GNMAT(64,72), KEMAT(3,2628), G(1575), P(1575)	GVC	200
	M=0	GVC	210
	DO 20 I=1,72	GVC	220
	K=GNMAT(INEL,I)	GVC	230
	DO 20 J=1,72	GVC	240
	L=GNMAT(INEL,J)	GVC	250
	M=M+1	GVC	260
	G(K)=G(K)+K(MAT(ITEL,M))*P(L)	GVC	270
	IF(I.EQ.J) GO TO 20	GVC	280
	G(L)=G(L)+KEMAT(ITEL,M)*P(K)	GVC	290
20	CONTINUE	GVC	300
	RETURN	GVC	310
	END	GVC	320

C	MAIN PROGRAM STEP 3 (ITERATION FROM DISK VERSION)	ESD	10
C		ESD	20
C	*****	* ESD	30
C		* ESD	40
C	* STEP 3 PERFORMS FIVE FUNCTIONS	* ESD	50
C		* ESD	60
C	* 1. COMBINES NON-ZERO DISPLACEMENT BOUNDARY CONDITIONS WITH	* ESD	70
C	THE FORCE VECTOR	* ESD	80
C		* ESD	90
C	* 2. SOLVES THE SYSTEM OF LINEAR EQUATIONS BY MINIMIZING THE	* ESD	100
C	TOTAL POTENTIAL ENERGY	* ESD	110
C		* ESD	120
C	* 3. CALCULATES AND PRINTS THE STRAIN ENERGY AND OTHER	* ESD	130
C	CONVERGENCE PARAMETERS	* ESD	140
C		* ESD	150
C	* 4. PRINTS THE COORDINATE AND THREE (X,Y,&Z) DISPLACEMENTS	* ESD	160
C	AT EACH NODE	* ESD	170
C		* ESD	180
C	* 5. WRITES DISPLACEMENTS ON DISK AND/OR CARDS	* ESD	190
C		* ESD	200
C	*****	* ESD	210
C		ESD	220
C	*****	* ESD	230
C		* ESD	240
C	* VARIABLE DEFINITIONS AND DIMENSIONS FOR STEP 3	* ESD	250
C		* ESD	260
C	* ACB - - - - - CHANGE IN STRAIN ENERGY OVER STRAIN ENERGY	* ESD	270
C		* ESD	280
C	* B(NGLDF) - - - - - FORCE VECTOR	* ESD	290
C		* ESD	300
C	* BNRM - - - - - MAGNITUDE OF THE FORCE VECTOR	* ESD	310
C		* ESD	320
C	* DBC(MM) - - - - - NON-ZERO DISPLACEMENT BOUNDARY CONDITIONS	* ESD	330
C		* ESD	340
C	* DELE - - - - - CHANGE IN STRAIN ENERGY	* ESD	350
C		* ESD	360
C	* DELXNR - - - - - MAGNITUDE OF THE CHANGE IN DISPLACEMENT	* ESD	370
C	VECTOR	* ESD	380
C		* ESD	390
C	* ENGY1 - - - - - STRAIN ENERGY	* ESD	400
C		* ESD	410
C	* ENGY2 - - - - - SYRAIN ENERGY	* ESD	420
C		* ESD	430
C	* EPS - - - - - ENERGY CONVERGENCE TEST PARAMETER	* ESD	440
C		* ESD	450
C	* G(NGLDF) - - - - - RESULTING VECTOR FROM KX OR KP MATRIX-	* ESD	460
C	VECTOR PRODUCT	* ESD	470
C		* ESD	480
C	* GNMAT(NEL,72) - - RELATES LOCAL AND GLOBAL DEGREES-OF-FREEDOM	* ESD	490
C		* ESD	500
C	* ICRD - - - - - UNIT NUMBER FOR CARD READER	* ESD	510

C	*		* ESD	520
C	*	IUDA - - - - - UNIT NUMBER FOR DIRECT ACCESS FILE	* ESD	530
C	*		* ESD	540
C	*	IX26(NEL) - - - - ELEMENT TYPE FOR EACH ELEMENT	* ESD	550
C	*		* ESD	560
C	*	KEMAT(2628) - - - UPPER SYMMETRIC PORTION OF AN ELEMENT	* ESD	570
C	*	STIFFNESS MATRIX STORED AS A ONE DIMENSIONAL	* ESD	580
C	*	ARRAY	* ESD	590
C	*		* ESD	600
C	*	KOUNT - - - - - TOTAL NUMBER OF ITERATIONS	* ESD	610
C	*		* ESD	620
C	*	LDBC(NDBC) - - - - INDEX FOR DISPLACEMENT BOUNDARY CONDITIONS	* ESD	630
C	*		* ESD	640
C	*	LIST - - - - - UNIT NUMBER FOR PRINTER	* ESD	650
C	*		* ESD	660
C	*	LLDBC(MM) - - - - INDEX NUMBERS FOR NON-ZERO DISPLACEMENT	* ESD	670
C	*	BOUNDARY CONDITIONS	* ESD	680
C	*		* ESD	690
C	*	MM - - - - - NUMBER OF NON-ZERO DISPLACEMENT BOUNDARY	* ESD	700
C	*	CONDITIONS	* ESD	710
C	*		* ESD	720
C	*	NDBC - - - - - NUMBER OF DISPLACEMENT BOUNDARY CONDITIONS	* ESD	730
C	*		* ESD	740
C	*	NEL - - - - - NUMBER OF ELEMENTS	* ESD	750
C	*		* ESD	760
C	*	NGLDF - - - - - NUMBER OF DEGREES-OF-FREEDOM (GLOBAL SYSTEM)	* ESD	770
C	*		* ESD	780
C	*	NTYEL - - - - - NUMBER OF UNIQUE ELEMENTS	* ESD	790
C	*		* ESD	800
C	*	P(INGLDF) - - - - - CORRECTION VECTOR IN CONJUGATE GRADIENT	* ESD	810
C	*	ROUTINE	* ESD	820
C	*		* ESD	830
C	*	R(INGLDF) - - - - - RESIDUE VECTOR IN CONJUGATE GRADIENT	* ESD	840
C	*	ROUTINE	* ESD	850
C	*		* ESD	860
C	*	RNRM - - - - - MAGNITUDE OF THE RESIDUE VECTOR	* ESD	870
C	*		* ESD	880
C	*	UX(NGNP) - - - - - DISPLACEMENTS IN THE X-DIRECTION	* ESD	890
C	*		* ESD	900
C	*	UY(NGNP) - - - - - DISPLACEMENTS IN THE Y-DIRECTION	* ESD	910
C	*		* ESD	920
C	*	UZ(NGNP) - - - - - DISPLACEMENTS IN THE Z-DIRECTION	* ESD	930
C	*		* ESD	940
C	*	X(INGLDF) - - - - - DISPLACEMENT VECTOR	* ESD	950
C	*		* ESD	960
C	*	XCORD(NGNP) - - - X-COORDINATE (GLOBAL SYSTEM)	* ESD	970
C	*		* ESD	980
C	*	XI(NGNP) - - - - - R-COORDINATE (GLOBAL SYSTEM)	* ESD	990
C	*		* ESD	1000
C	*	YCORD(NGNP) - - - Y-COORDINATE (GLOBAL SYSTEM)	* ESD	1010
C	*		* ESD	1020


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C   CAUTION: DO NOT DIMENSION UX GREATER THAN 1314 - SEE EQUIVALENCE ESD 1540
C   STATEMENT 8110W ESD 1550
C ESD 1560
C   DIMENSION XCORD(952), YCORD(952), ZCORD(952), ESD 1570
C   1 UX(952), UY(952), UZ(952) ESD 1580
C   EQUIVALENCE (XCORD(1),G(1)), (YCORD(1),B(1)), (ZCORD(1),P(1)) ESD 1590
C   EQUIVALENCE (XEMAT(1),UX(1)), (KEMAT(1315),UY(1)), ESD 1600
C   1 (K(1),UZ(1)) ESD 1610
100 FORMAT(2I5,2F10.0, 15 ) ESD 1620
102 FORMAT(5Z16) ESD 1630
201 FORMAT('OMAXIMUM NUMBER OF ITERATIONS FOR THIS RUN IS' , 15) ESD 1640
301 FORMAT('DELTA STRAIN ENERGY / STRAIN ENERGY DID CONVERGE TO ' ESD 1650
C   1 , E14.7, ' AFTER' , 16, ' ITERATIONS AND ACCURATE TO',E14.7) ESD 1660
302 FORMAT(' TIME IN CG SUBROUTINE IS ' , F7.2, ' SECONDS') ESD 1670
303 FORMAT('DELTA STRAIN ENERGY / STRAIN ENERGY DID NOT CONVERGE TO ' ESD 1680
C   1 , E14.7, ' AFTER' , 16, ' ITERATIONS BUT ACCURATE TO',E14.7) ESD 1690
304 FORMAT('O' , G14.7, ' IS THE INITIAL GUESS FOR ALL DISPLACEMENTS') ESD 1700
305 FORMAT ('OTHE INITIAL GUESSES FOR DISPLACEMENTS ARE READ FROM CARDESD 1710
C   1S AND MULTIPLIED BY A FACTOR OF' , G14.7) ESD 1720
306 FORMAT ('OTHE INITIAL GUESSES FOR DISPLACEMENTS ARE READ FROM CARDESD 1730
C   1S AND THE Z-DISPLACEMENTS ARE MULTIPLIED BY A FACTOR OF', G14.7) ESD 1740
307 FORMAT('OTHE INITIAL GUESSES FOR DISPLACEMENTS ARE READ FROM DISK' ESD 1750
C   1 ) ESD 1760
308 FORMAT('OSTRAIN ENERGY', T50, E14.7 , ' K IN-LBS' / ESD 1770
C   1 ' CHANGE IN STRAIN ENERGY', T50, E14.7 , ' K IN-LBS' / ESD 1780
C   2 ' MAGNITUDE OF THE RESIDUE VECTOR', T50, E14.7 , ' K LBS' / ESD 1790
C   3 ' MAGNITUDE OF THE FORCE VECTOR', T50, E14.7 , ' K LBS' / ESD 1800
C   4 ' MAGNITUDE OF THE CHANGE IN DISPLACEMENT VECTOR',T50,E14.7 ESD 1810
C   5, ' IN' / ' MAGNITUDE OF THE DISPLACEMENT VECTOR', T50, E14.7, ' IN') ESD 1820
2000 FORMAT('O',7X,'NODE',13X,'X-COORD',13X, 'Y-COORD',13X, 'Z-COORD', ESD 1830
C   1 9X, 'X-DISPL', 13X, 'Y-DISPL',13X, 'Z-DISPL' / ESD 1840
C   2 27X, 'INS', 17X, 'INS',17X, 'INS', 13X, 'INS', 17X, 'INS', ESD 1850
C   3 17X, 'INS' / ) ESD 1860
2001 FORMAT(6X, 15, 3F20.5, 3E20.7) ESD 1870
C   DEFINE FILE 3(55,6500,U,IDXDA) ESD 1880
C   IUDA = 3 ESD 1890
C   ICRD = 5 ESD 1900
C   LIST = 6 ESD 1910
C ESD 1920
C   READ CARD DATA FOR STEP 3 ESD 1930
C ESD 1940
C   READ(ICRD,100)INTXMD,ITRLMT, FACTOR, EPS, IDSPL ESD 1950
C ESD 1960
C   READ DATA GENERATED IN STEP 2 ESD 1970
C ESD 1980
C   READ (IUDA*1) NEL, NGLDF, NDBC, NTYEL, LIMIT, NGNP,NMTL, ESD 1990
C   1 HED, IPAGE, AMBTMP ESD 2000
C   READ (IUDA*4) ( B(J),J=1,NGLDF) ESD 2010
C   1 , SW, NOCNV, (LDBC(J),J=1,NDBC) ESD 2020
C   READ (IUDA*5) ( P(J),J=1,NGLDF) ESD 2030
C   1 , (IX26(J),J=1,NEL) ESD 2040

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READ (IUDA*6) ((GNMAT(I,J),J=1,72),I=1,NEL)	ESD 2050
IDXDA = NTYEL+7	ESD 2060
CALL TITLE	ESD 2070
WRITE(LIST,201) ITRLMT	ESD 2080
C	ESD 2090
C DETERMINE INITIAL GUESS FOR THE DISPLACEMENT VECTOR	ESD 2100
C	ESD 2110
GO TO (21,22,23,24), INTXMD	ESD 2120
21 DO 50 I=1,NGLOF	ESD 2130
50 X(I) = FACTOR	ESD 2140
WRITE(LIST,304) FACTOR	ESD 2150
GO TO 29	ESD 2160
22 READ(5,102) (X(J),J=1,NGLOF)	ESD 2170
DO 61 I=1,NGLOF	ESD 2180
61 X(I) = FACTOR*X(I)	ESD 2190
WRITE(LIST,305) FACTOR	ESD 2200
GO TO 29	ESD 2210
23 READ(5,102) (X(J),J=1,NGLOF)	ESD 2220
DO 10 I=1,NGNP	ESD 2230
10 X(3*I) = FACTOR*X(3*I)	ESD 2240
WRITE(LIST,306) FACTOR	ESD 2250
GO TO 29	ESD 2260
24 READ (IUDA*IDXDA)SW,MM, (DBC(J),J=1,MM), (LLDBC(J),J=1,MM), KOUNT,	ESD 2270
1 (X(J),J=1,NGLOF)	ESD 2280
SW(8) = .TRUE.	ESD 2290
SW(3) = .FALSE.	ESD 2300
35 IF(.NOT. SW(10)) GO TO 33	ESD 2310
MM = 0	ESD 2320
33 READ (IUDA*IDXDA) (B(J),J=1,NGLOF)	ESD 2330
WRITE(LIST,307)	ESD 2340
GO TO 34	ESD 2350
29 CONTINUE	ESD 2360
C	ESD 2370
C CONVERT INITIAL DISPLACEMENT BOUNDARY CONDITIONS TO FORCE BOUNDARY	ESD 2380
C CONDITIONS	ESD 2390
C	ESD 2400
MM = 0	ESD 2410
DO 60 I=1,NGLOF	ESD 2420
IF(DABS(P(I)) .LT. 1.0-14) GO TO 60	ESD 2430
MM = MM + 1	ESD 2440
DBC(MM) = P(I)	ESD 2450
LLDBC(MM) = I	ESD 2460
60 CONTINUE	ESD 2470
DO 13 I=1,NGLOF	ESD 2480
13 G(I) = 0.00	ESD 2490
DO 15 INEL=1,NEL	ESD 2500
LOE = IX26(INEL) + 6	ESD 2510
READ(3*LOE) KEMAT	ESD 2520
15 CALL GVT(GNMAT, KEMAT, G, P, INEL)	ESD 2530
DO 80 I=1,NGLOF	ESD 2540
80 B(I) = B(I) - G(I)	ESD 2550

34 CALL TIMON	ESD 2560
C	ESD 2570
C MINIMIZE TOTAL POTENTIAL ENERGY	ESD 2580
C	ESD 2590
CALL CGJRD	ESD 2600
CALL TIMECK(ITIME)	ESD 2610
SEC = ITIME/100.	ESD 2620
C	ESD 2630
C WRITE FORCE AND DISPLACEMENT DATA ON DISK FOR USE IN FUTURE RUNS	ESD 2640
C	ESD 2650
IF(MM .NE. 0) GO TO 31	ESD 2660
SW(10) = .TRUE.	ESD 2670
MM = 1	ESD 2680
DBC(1) = CDO	ESD 2690
21 IDXDA = NYEL + 7	ESD 2700
WRITE(IUDA*IDXDA)SW,MM, (DEC(J),J=1,MM), (LLDBC(J),J=1,MM), KOUNT,	ESD 2710
1 (X(J),J=1,NGLOF)	ESD 2720
WRITE(IUDA*IDXDA) (B(J),J=1,NGLOF)	ESD 2730
C	ESD 2740
C PRINT STRAIN ENERGY AND CONVERGENCE DATA	ESD 2750
C	ESD 2760
IF(SW(1)) GO TO 20	ESD 2770
WRITE(LIST,303) EPS, KOUNT, ACB	ESD 2780
GO TO 9	ESD 2790
20 WRITE(LIST,301) EPS, KOUNT, ACB	ESD 2800
9 WRITE(LIST,302) SEC	ESD 2810
WRITE(LIST,308) ENGY1, DELE, RNRH, BNRH, DELXNR, XNRH	ESD 2820
IF(IDSPL .EQ. C) GO TO 32	ESD 2830
IF(IDSPL .EQ. 2) GO TO 43	ESD 2840
C	ESD 2850
C PRINT AND/OR PUNCH THE DISPLACEMENT VECTOR	ESD 2860
C	ESD 2870
READ(IUDA*3)(XCORD(J),J=1,NGNP), (YCORD(J),J=1,NGNP),	ESD 2880
1 (ZCORD(J),J=1,NGNP)	ESD 2890
CALL TITLE	ESD 2900
WRITE(LIST,2000)	ESD 2910
DO 30 I=1,NGNP	ESD 2920
IF(LINE .LT. 48) GO TO 94	ESD 2930
CALL TITLE	ESD 2940
WRITE(LIST,2000)	ESD 2950
94 CONTINUE	ESD 2960
LINE = LINE + 1	ESD 2970
UX(I) = X(3*I-2)	ESD 2980
UY(I) = X(3*I-1)	ESD 2990
UZ(I) = X(3*I)	ESD 3000
30 WRITE(LIST,2001) 1, XCURD(I), YCORD(I), ZCORD(I),	ESD 3010
1 UX(I), UY(I), UZ(I)	ESD 3020
IF(IDSPL .EQ. 1) GO TO 32	ESD 3030
43 WRITE(7,102) (X(I),I=1,NGLOF)	ESD 3040
32 STOP	ESD 3050
END	ESD 3060

C	SUBROUTINE CGJRD	CGD 10
C		CGD 20
C	*****	CGD 30
C	*	CGD 40
C	* SUBROUTINE CGJRD MINIMIZES THE TOTAL POTENTIAL ENERGY BY THE	CGD 50
C	* CONJUGATE GRADIENT METHOD AND TESTS THE STRAIN ENERGY FOR	CGD 60
C	* CONVERGENCE	CGD 70
C	*	CGD 80
C	* THIS SUBROUTINE IS CALLED BY -	CGD 90
C	* MAIN	CGD 100
C	*	CGD 110
C	* THIS SUBROUTINE CALLS	CGD 120
C	* GVT	CGD 130
C	*	CGD 140
C	*****	CGD 150
C		CGD 160
C		CGD 170
C	IMPLICIT REAL*8 (A-H,O-Z)	CGD 180
	REAL*8 KEMAT	CGD 190
	INTEGER*2 GNMAT, LDRC, LLDBC, IX26	CGD 200
	LOGICAL*1 SW	CGD 210
	COMMON / KEGN / KEMAT(2628), GNMAT(120,72), IX26(121)	CGD 220
	COMMON / CGVECT / G(2856), X(2856), B(2856), P(2856), R(2856)	CGD 230
	COMMON / SCALAR / EPS, ACB, XNRM, BNRM, RNRN, DELXNR,	CGD 240
	1 DELE, ENGY1, INGY2,	CGD 250
	2 NGLUF, LIMIT, NEL, KOUNT, ITYEL, ITRLMT, MM	CGD 260
	COMMON / BC / DRC(200), LLDBC(200), LDRC(700), NDBC	CGD 270
	COMMON / SWITCH / SW(12)	CGD 280
	ITKNT = 0	CGD 290
	IF(SW(8)) GO TO 2	CGD 300
	KOUNT = 0	CGD 310
	BETA = 0.00	CGD 320
C		CGD 330
C	RESTART ITERATIVE PROCESS BY FINDING NEW RESIDUE VECTOR	CGD 340
C		CGD 350
	2 DO 10 I = 1, NGLUF	CGD 360
	10 G(I) = 0.00	CGD 370
	DO 70 I=1, NDBC	CGD 380
	B(LDBC(I)) = 0.00	CGD 390
	70 X(LDBC(I)) = 0.00	CGD 400
	DO 31 INEL=1, NEL	CGD 410
	LQE = IX26(INEL) + 6	CGD 420
	READ(3, LQE) KEMAT	CGD 430
	31 CALL GVT(GNMAT, KEMAT, G, X, INEL)	CGD 440
	DO 32 I=1, NDBC	CGD 450
	32 G(LDBC(I)) = 0.00	CGD 460
	RNRH1 = 0.00	CGD 470
	DO 20 I = 1, NGLDF	CGD 480
	P(I) = B(I) - G(I)	CGD 490
	R(I) = P(I)	CGD 500
	20 RNRH1 = RNRH1 + R(I) * R(I)	CGD 510

C		CGD	520
C	CALCULATE STRAIN ENERGY	CGD	530
C		CGD	540
	IF (.NOT. (SW(3) .OR. SW(4))) GO TO 5	CGD	550
	IF (MM .EQ. 0) GO TO 95	CGD	560
	DO 40 I=1,MM	CGD	570
	90 X(LLDBC(I)) = DBC(I)	CGD	580
	95 ENGY1 = 0.00	CGD	590
	DO 17 I=1,NGLDF	CGD	600
	17 G(I) = 0.00	CGD	610
	DO 34 INEL=1,NEL	CGD	620
	LQE = IX26(INEL) + 6	CGD	630
	READ(3,LQE) KEMAT	CGD	640
	34 CALL GVT(GNMAT, KEMAT, G, X, INEL)	CGD	650
	DO 92 I=1,NGLDF	CGD	660
	92 ENGY1 = ENGY1 + X(I) * G(I)	CGD	670
	ENGY1 = .5DC * ENGY1	CGD	680
	ENGY2 = ENGY1	CGD	690
C		CGD	700
C	FIND ALFA	CGD	710
C		CGD	720
	5 DO 35 I=1,NGLDF	CGD	730
	35 G(I) = 0.00	CGD	740
	DO 33 INEL=1,NEL	CGD	750
	LQE = IX26(INEL) + 6	CGD	760
	READ(3,LQE) KEMAT	CGD	770
	33 CALL GVT(GNMAT, KEMAT, G, P, INEL)	CGD	780
	DO 36 I=1,NDBC	CGD	790
	36 G(LDBC(I)) = 0.00	CGD	800
	PKP = 0.00	CGD	810
	DO 30 I = 1,NGLDF	CGD	820
	30 PKP = PKP + P(I) * G(I)	CGD	830
	ALFA = RNRM1 / PKP	CGD	840
	IF (SW(3)) GO TO 25	CGD	850
C		CGD	860
C	CORRECT THE DISPLACEMENT VECTOR	CGD	870
C		CGD	880
	DO 40 I = 1,NGLDF	CGD	890
	40 X(I) = X(I) + ALFA * P(I)	CGD	900
	ITKNT = ITKNT + 1	CGD	910
	KOUNT = KOUNT + 1	CGD	920
	IF (ITKNT .LT. ITRIMT) GO TO 7	CGD	930
	SW(3) = .TRUE.	CGD	940
	GO TO 2	CGD	950
	7 IF (SW(4)) GO TO 12	CGD	960
	IF (RNRM1 .GT. 1.) GO TO 11	CGD	970
	SW(4) = .TRUE.	CGD	980
	GO TO 2	CGD	990
	11 RNRM2 = 0.00	CGD	1000
C		CGD	1010
C	FIND NEW RESIDUE VECTOR AND NEW P VECTOR	CGD	1020

C	DO 50 I = 1, NGLDF	CGD 1030
	R(I) = K(I) - ALFA * G(I)	CGD 1040
50	RNRM2 = RNRM2 + R(I) * R(I)	CGD 1050
	BETA = RNRM2 / RNRM1	CGD 1060
	DO 60 I = 1, NGLDF	CGD 1070
60	P(I) = R(I) + BETA * P(I)	CGD 1080
	RNRM1 = RNRM2	CGD 1090
	GO TO 5	CGD 1100
C		CGD 1110
C	FIND CHANGE IN STRAIN ENERGY FROM ALFA & RNRM1	CGD 1120
C		CGD 1130
	12 DELE = .500 * ALFA * RNRM1	CGD 1140
	ENG2 = ENG2 - DELE	CGD 1150
	IF (DELE / ENG2 .LT. EPS) GO TO 14	CGD 1160
	SW(2) = .FALSE.	CGD 1170
	GO TO 11	CGD 1180
	14 IF (SW(2)) GO TO 15	CGD 1190
	SW(2) = .TRUE.	CGD 1200
	GO TO 2	CGD 1210
	15 SW(1) = .TRUE.	CGD 1220
C		CGD 1230
C	CALCULATE CONVERGENCE PARAMETERS	CGD 1240
C		CGD 1250
	25 XNRM = 0.00	CGD 1260
	BNRM = 0.00	CGD 1270
	DELXNR = 0.00	CGD 1280
	DO 16 I = 1, NGLDF	CGD 1290
	XNRM = XNRM + X(I) * X(I)	CGD 1300
	BNRM = BNRM + B(I) * B(I)	CGD 1310
16	DELXNR = DELXNR + P(I) * P(I)	CGD 1320
	XNRM = DSORT(XNRM)	CGD 1330
	BNRM = DSORT(BNRM)	CGD 1340
	RNRM = DSORT(RNRM1)	CGD 1350
	DELXNR = ALFA * DSORT(DELXNR)	CGD 1360
	IF (.NOT. SW(2)) DELE = .500 * ALFA * RNRM1	CGD 1370
	ACF = DELE / ENG2	CGD 1380
	RETURN	CGD 1390
	END	CGD 1400
		CGD 1410

	SUBROUTINE TITLE	TID	10
C		TID	20
C	* * * * *	TID	30
C	*	TID	40
C	* SUBROUTINE TITLE PRINTS THE HEADING ON EACH PAGE	TID	50
C	* THIS SUBROUTINE IS CALLED BY -	TID	60
C	* MAIN	TID	70
C	*	TID	80
C	* * * * *	TID	90
C		TID	100
	IMPLICIT REAL*8 (A-H,O-Z)	TID	110
	COMMON / HEAD / HED(10),ICRD,LIST,IPAGE,LINE	TID	120
100	FORMAT (1H1,'FEM 72-DOF GENERAL HEXAHEDRONS THERMO-ELASTIC, VARYINT	TID	130
	1G MATERIAL PROPERTIES, DANA', 9X, 'PAGE', 13)	TID	140
101	FORMAT (1H0,10A8)	TID	150
	LIST = 6	TID	160
	NIWRT = 6	TID	170
	WRITE (LIST,10:) IPAGE	TID	180
	WRITE (LIST,101) HED	TID	190
	IPAGE= IPAGE +1	TID	200
	LINE = 0	TID	210
	RETURN	TID	220
	END	TID	230

	SUBROUTINE GVT(GNMAT,KEMAT,G,P,INEL)	GVD	10
C		GVD	20
C	* * * * *	* GVD	30
C	* * * * *	* GVD	40
C	* SUBROUTINE GVT FORMS THE MATRIX-VECTOR PRODUCT KP=G WHERE K	* GVD	50
C	* REPRESENTS THE NON-FORMED GLOBAL STIFFNESS MATRIX	* GVD	60
C	* * * * *	* GVD	70
C	* THIS SUBROUTINE IS CALLED BY -	* GVD	80
C	* MAIN	* GVD	90
C	* CGJRD	* GVD	100
C	* * * * *	* GVD	110
C	* NOTE: OVER 90 PERCENT OF THE TIME IN STEP 3 IS SPENT IN THIS	* GVD	120
C	* SUBROUTINE - IT IS RECOMMEND THAT THIS SUBROUTINE BE REWRITTEN	* GVD	130
C	* IN ASSEMBLY LANGUAGE TO OPTIMIZE THE CODE.	* GVD	140
C	* * * * *	* GVD	150
C	* * * * *	* GVD	160
C		GVD	170
	.REAL*8 KEMAT, G , P	GVD	180
	INTEGER*2 GNMAT	GVD	190
	DIMENSION GNMAT(120,72), KEMAT(2628), G(2856), P(2856)	GVD	200
	M=C	GVD	210
	DO 20 I=1,72	GVD	220
	K=GNMAT(INEL,I)	GVD	230
	DO 20 J=1,72	GVD	240
	L=GNMAT(INEL,J)	GVD	250
	M=M+1	GVD	260
	G(K)=G(K)+KEMAT(M)*P(L)	GVD	270
	IF(I.EQ.J) GO TO 20	GVD	280
	G(L)=G(L)+KEMAT(M)*P(K)	GVD	290
20	CONTINUE	GVD	300
	RETURN	GVD	310
	END	GVD	320

C	MAIN PROGRAM STEP 4	MN4.	10
C		MN4	20
C	* * * * *	MN4	30
C	* STEP 4 PERFORMS THREE FUNCTIONS	* MN4	40
L	*	* MN4	50
L	* 1. READ PROBLEM DATA AND DISPLACEMENTS FROM DISK	* MN4	60
C	*	* MN4	70
C	* 2. CALCULATES SIX STRESS COMPONENTS AT EACH NODE FOR EACH	* MN4	80
C	* ELEMENT IN RECTANGULAR OR CYLINDRICAL COORDINATES	* MN4	90
C	*	* MN4	100
C	* 3. PRINTS STRESSES AND/OR CYLINDRICAL DISPLACEMENTS	* MN4	110
C	*	* MN4	120
C	* * * * *	* MN4	130
C		MN4	140
C	* * * * *	* MN4	150
C	*	* MN4	160
C	* VARIABLE DEFINITIONS AND DIMENSIONS FOR STEP 4	* MN4	170
C	*	* MN4	180
C	* ALFA1(NMTL) - - - THERMAL EXPANSION COEFFICIENT 11	* MN4	190
C	*	* MN4	200
C	* ALFA2(NMTL) - - - THERMAL EXPANSION COEFFICIENT 22	* MN4	210
C	*	* MN4	220
C	* ALFA3(NMTL) - - - THERMAL EXPANSION COEFFICIENT 33	* MN4	230
C	*	* MN4	240
C	* AMBTMP - - - - - INITIAL TEMPERATURE	* MN4	250
C	*	* MN4	260
C	* D(6,6) - - - - - ELASTIC MATRIX	* MN4	270
C	*	* MN4	280
C	* E(NMTL,9,NTMP) - - MATERIAL PROPERTIES	* MN4	290
C	*	* MN4	300
C	* ETH(9) - - - - - NINE INDEPENDENT ORTHOTROPIC MATERIAL	* MN4	310
C	* CONSTANTS	* MN4	320
C	*	* MN4	330
C	* FIBORT(NMTL) - - - DIRECTION OF PRINCIPAL AXIS FOR EACH	* MN4	340
C	* MATERIAL	* MN4	350
C	*	* MN4	360
C	* ICRD - - - - - UNIT NUMBER FOR CARD READER	* MN4	370
C	*	* MN4	380
C	* ISTRS - - - - - CODE TO SPECIFY STRESSES IN RECTANGULAR OR	* MN4	390
C	* CYLINDRICAL COORDINATES	* MN4	400
C	*	* MN4	410
C	* IUOA - - - - - UNIT NUMBER FOR DIRECT ACCESS FILE	* MN4	420
C	*	* MN4	430
C	* IX(NEL,27) - - - - RELATES LOCAL AND GLOBAL NODAL POINTS	* MN4	440
C	*	* MN4	450
C	* LIST - - - - - UNIT NUMBER FOR PRINTER	* MN4	460
C	*	* MN4	470
C	* MTLND(NGNP) - - - MATERIAL AT EACH NODE	* MN4	480
C	*	* MN4	490
C	* NEL - - - - - NUMBER OF ELEMENTS	* MN4	500
C	*	* MN4	510

C	READ(ICRD,100) ISTRS	MN4 1030
C		MN4 1040
C	READ DATA GENERATED IN STEP 2 - PROBLEM DATA	MN4 1050
C		MN4 1060
	READ (IUDA*1) MCL, NGLDF, NOBC, NTYEL, LIMIT, NGNP, NMTL,	MN4 1070
	1 HED, IPAGE, AMBTMP	MN4 1080
	READ (IUDA*2) ((NTMP(J), FIBORT(J), ALFA1(J), ALFA2(J), ALFA3(J)),	MN4 1090
	1 (TMPEL(J,1), (E(J,L,1),L=1,9), I=1,10), J=1,NMTL)	MN4 1100
	2 , ((IX(I,J),J=1,27),I=1,NEL),	MN4 1110
	3 (TMPND(J), MTLND(J),J=1,NGNP)	MN4 1120
	READ (IUDA*3) (X(J),J=1,NGNP), (Y(J),J=1,NGNP), (Z(J),J=1,NGNP)	MN4 1130
C		MN4 1140
C	READ DATA GENERATED IN STEP 3 - DISPLACEMENTS	MN4 1150
C		MN4 1160
	IDXDA = NTYEL+7	MN4 1170
	READ (IUDA*IDXDA)SW,MM, (DBC(J),J=1,MM), (LLDBC(J),J=1,MM), KOUNT,	MN4 1180
	1 (U(J),J=1,NGLDF)	MN4 1190
	IF(ISTRS .EQ. 0) GO TO 12	MN4 1200
C		MN4 1210
C	TRANSFORM X AND Y RECTANGULAR COORDINATES TO R AND THETA	MN4 1220
C	CYLINDRICAL COORDINATES	MN4 1230
C		MN4 1240
	DO 3 I=1,NGNP	MN4 1250
	XT(I) = DSQRT(X(I)*X(I) + Y(I)*Y(I))	MN4 1260
	3 YT(I) = 180.00 * DATAN2(Y(I), X(I)) / 3.1415926535897900	MN4 1270
	IF(ISTRS .EQ. 1) GO TO 12	MN4 1280
C		MN4 1290
C	PRINT DISPLACEMENTS IN CYLINDRICAL COORDINATES	MN4 1300
C		MN4 1310
	CALL TITLE	MN4 1320
	WRITE(LIST,2000)	MN4 1330
	DO 30 I=1,NGNP	MN4 1340
	IF(LINE .LT. 48) GO TO 94	MN4 1350
	CALL TITLE	MN4 1360
	WRITE(LIST,2000)	MN4 1370
	94 CONTINUE	MN4 1380
	LINE = LINE + 1	MN4 1390
	UX(I) = U(3*I-2) * DCOS(3.1415926535897900 * YT(I) / 180.00)	MN4 1400
	1 + U(3*I-1) * DSIN(3.1415926535897900 * YT(I) / 180.00)	MN4 1410
	UY(I) = -U(3*I-2) * DSIN(3.1415926535897900 * YT(I) / 180.00)	MN4 1420
	1 + U(3*I-1) * DCOS(3.1415926535897900 * YT(I) / 180.00)	MN4 1430
	UZ(I) = U(3*I)	MN4 1440
	30 WRITE(LIST,2001) I, XT(I), YT(I), Z(I), UX(I), UY(I), UZ(I)	MN4 1450
	IF(ISTRS .EQ. 2) GO TO 9	MN4 1460
C		MN4 1470
C	CALCULATE STRESSSES	MN4 1480
C		MN4 1490
	12 CALL STRESS	MN4 1500
	9 STOP	MN4 1510
	END	MN4 1520
		MN4 1530

	SUBROUTINE TITLE	TI4	10
C	* * * * *	TI4	20
C	*	TI4	30
C	* SUBROUTINE TITLE PRINTS THE HEADING ON EACH PAGE	TI4	40
C	*	TI4	50
C	* THIS SUBROUTINE IS CALLED BY -	TI4	60
C	* STRESS	TI4	70
C	*	TI4	80
C	* * * * *	TI4	90
C		TI4	100
	IMPLICIT REAL*8 (A-H,O-Z)	TI4	110
	COMMON / HEAD / HED(10),ICKD,LIST,IPAGE,LINE	TI4	120
100	FORMAT (1H1,'FEM 72-DOF GENERAL HEXAEDRONS THERMO-ELASTIC, VARYINT	TI4	130
	1G MATERIAL PROPERTIES, DANA', 9X, 'PAGE', I3)	TI4	140
101	FORMAT (1H0,10A8)	TI4	150
	WRITE (LIST,100) IPAGE	TI4	160
	WRITE (LIST,101) HED	TI4	170
	IPAGE= IPAGE +1	TI4	180
	LINE = 0	TI4	190
	RETURN	TI4	200
	END	TI4	210

C	SUBROUTINE STRESS	ST4	10
C		ST4	20
C	* * * * *	ST4	30
C	* * * * *	ST4	40
C	* SUBROUTINE STRESS CALCULATES AND PRINTS THE SIX STRESS	ST4	50
C	* COMPONENTS AT EACH NODE FOR EACH ELEMENT	ST4	60
C	* * * * *	ST4	70
C	* THIS SUBROUTINE IS CALLED BY -	ST4	80
C	* MAIN	ST4	90
C	* * * * *	ST4	100
C	* THIS SUBROUTINE CALLS -	ST4	110
C	* TITLE	ST4	120
C	* ELASTR	ST4	130
C	* * * * *	ST4	140
C	* * * * *	ST4	150
C		ST4	160
	IMPLICIT REAL*8 (A-H,O-Z)	ST4	170
	.INTEGER*2 IX, MTLND	ST4	180
	COMMON / GENLS / NLL, NGLDF, NGNP, NMTL, INEL, ILNP, IGNP, IMTL	ST4	190
	COMMON / MATL / E(9,9,10), D(6,6), FIBURT(9), ALFA1(9),	ST4	200
	1 ALFA2(9), ALFA3(9), AMBTMP, ETM(9), TMEPL(9,10), NTMP(9)	ST4	210
	COMMON / NODAL / X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	ST4	220
	1 UZ(1015), TMPND(1015), U(3045), ALFTMP(6), XT(1015), YT(1015),	ST4	230
	2 ISTRS, IX(144,27), MTLND(1015)	ST4	240
	COMMON / HEAD / HED(10), ICRD, LIST, IPAGE, LINE	ST4	250
	DIMENSION XYZ(24,3), C(3,24), DJI(3,3), DJI(3,3), BA(6,72),	ST4	260
	1 BDB(72,72), SIG(6), UEL(72), SIGSAV(6,24), T(3,3),	ST4	270
	2 SIGRTH(3,3), SIGXY(3,3)	ST4	280
	2000 FORMAT (1H0,9X,6HEL.NO.,6X,4HNUDE,9X,8HX-STRESS,6X,8HY-STRESS,	ST4	290
	16X, 8HZ-STRESS,6X, 8HXY-STRESS,5X,9HXZ-STRESS,5X,9HYZ-STRESS/	ST4	300
	2 37X, 'KSI', 10X, 'KSI', 12X, 'KSI', 11X, 'KSI', 11X, 'KSI',	ST4	310
	3 11X, 'KSI')	ST4	320
	2001 FORMAT (15X,111,4X,6D14.5)	ST4	330
	2002 FORMAT (1H0,9X,15,111,4X,6D14.5)	ST4	340
	2003 FORMAT('0 EL.NO. NODE R-STRESS THETA-STRESS	ST4	350
	15 Z-STRESS RTHETA-STRESS RZ-STRESS THETAZ-STRESS' /	ST4	360
	2 37X, 'KSI', 10X, 'KSI', 12X, 'KSI', 11X, 'KSI', 11X, 'KSI',	ST4	370
	3 11X, 'KSI')	ST4	380
	2004 FORMAT (15X,111,4X,6D14.5)	ST4	390
	2005 FORMAT (1H0,9X,15,111,4X,6D14.5)	ST4	400
C		ST4	410
C	SOLVE FOR STRESSES SIG(6) AT EACH NODAL POINTS OF EACH ELEMENT	ST4	420
C		ST4	430
	CALL TITLE	ST4	440
	IF(ISTRS.EQ. 0 .OR. ISTRS.EQ. 4) GO TO 31	ST4	450
	WRITE(LIST,2003)	ST4	460
	GO TO 32	ST4	470
	31 WRITE (LIST,2070)	ST4	480
	32 CONTINUE	ST4	490
	DD 300 INEL=1,NEL	ST4	500
C		ST4	510

C PLACE PROPER NODAL DISPLACEMENTS IN U FROM A	ST4 520
C	ST4 530
DO 121 I=1,24	ST4 540
UEL (3*I-2) = U(3*IX(INEL,I)-2)	ST4 550
UEL (3*I-1) = U(3*IX(INEL,I)-1)	ST4 560
121 UEL (3*I) = U(3*IX(INEL,I))	ST4 570
C	ST4 580
C FORM NODAL PT. COORDS. MATRIX XYZ FOR J(3X3) = C(3X24)*XYZ(24X3)	ST4 590
C	ST4 600
DO 140 I=1,24	ST4 610
L = IX(INEL,I)	ST4 620
XYZ(I,1) = X(L)	ST4 630
XYZ(I,2) = Y(L)	ST4 640
140 XYZ(I,3) = Z(L)	ST4 650
C	ST4 660
C CALCULATE BA = D*B, 24 SETS OF (6X72) FOR EACH NODE OF THE ELEMENT	ST4 670
C	ST4 680
DO 200 ILNP=1,24	ST4 690
DO 150 I=1,6	ST4 700
150 SIG(I) = 0.00	ST4 710
GO TO (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,	ST4 720
1 13,14,15,16,17,18,19,20, 21, 22, 23, 24), ILNP	ST4 730
1 XSII= -1.00	ST4 740
ETAA= -1.00	ST4 750
ZTAA= -1.00	ST4 760
GO TO 25	ST4 770
2 XSII= -1.00/3.00	ST4 780
GO TO 25	ST4 790
3 XSII= 1.00/3.00	ST4 800
GO TO 25	ST4 810
4 XSII= 1.00	ST4 820
GO TO 25	ST4 830
5 ZTAA= 1.00	ST4 840
XSII= -1.00	ST4 850
GO TO 25	ST4 860
6 XSII= -1.00/3.00	ST4 870
GO TO 25	ST4 880
7 XSII= 1.00/3.00	ST4 890
GO TO 25	ST4 900
8 XSII= 1.00	ST4 910
GO TO 25	ST4 920
9 ZTAA= -1.00	ST4 930
XSII= -1.00	ST4 940
ETAA= -1.00/3.00	ST4 950
GO TO 25	ST4 960
10 ETAA= 1.00/3.00	ST4 970
GO TO 25	ST4 980
11 XSII= 1.00	ST4 990
ETAA= -1.00/3.00	ST4 1000
GO TO 25	ST4 1010
12 ETAA= 1.00/3.00	ST4 1020

GO TO 25	ST4 1030
13 ZTAA= 1.00	ST4 1040
XSII= -1.00	ST4 1050
ETAA= -1.00/3.00	ST4 1060
GO TO 25	ST4 1070
14 ETAA= 1.00/3.00	ST4 1080
GO TO 25	ST4 1090
15 XSII= 1.00	ST4 1100
ETAA= -1.00/3.00	ST4 1110
GO TO 25	ST4 1120
16 ETAA= 1.00/3.00	ST4 1130
GO TO 25	ST4 1140
17 ETAA= 1.00	ST4 1150
ZTAA= -1.00	ST4 1160
XSII= -1.00	ST4 1170
GO TO 25	ST4 1180
18 XSII= -1.00/3.00	ST4 1190
GO TO 25	ST4 1200
19 XSII= 1.00/3.00	ST4 1210
GO TO 25	ST4 1220
20 XSII= 1.00	ST4 1230
GO TO 25	ST4 1240
21 ZTAA= 1.00	ST4 1250
XSII= -1.00	ST4 1260
GO TO 25	ST4 1270
22 XSII= -1.00/3.00	ST4 1280
GO TO 25	ST4 1290
23 XSII= 1.00/3.00	ST4 1300
GO TO 25	ST4 1310
24 XSII= 1.00	ST4 1320
25 CONTINUE	ST4 1330
C	ST4 1340
C FORM C MATRIX	ST4 1350
C	ST4 1360
C(1,1) = (1.00-ETAA)*(1.00-ZTAA)*(10.00+18.00*XSII-27.00*XSII**2 -	ST4 1370
1 9.00*ETAA**2)	ST4 1380
C(1,2) = (1.00-ETAA)*(1.00-ZTAA)*(81.00*XSII**2-18.00*XSII-27.00)	ST4 1390
C(1,3) = (1.00-ETAA)*(1.00-ZTAA)*(27.00-18.00*XSII-81.00*XSII**2)	ST4 1400
C(1,4) = (1.00-ETAA)*(1.00-ZTAA)*(27.00*XSII**2+9.00*ETAA**2+	ST4 1410
1 18.00*XSII-10.00)	ST4 1420
C(1,5) = (1.00-ETAA)*(1.00+ZTAA)*(10.00+18.00*XSII-27.00*XSII**2-	ST4 1430
1 9.00*ETAA**2)	ST4 1440
C(1,6) = (1.00-ETAA)*(1.00+ZTAA)*(81.00*XSII**2-18.00*XSII-27.00)	ST4 1450
C(1,7) = (1.00-ETAA)*(1.00+ZTAA)*(27.00-18.00*XSII-81.00*XSII**2)	ST4 1460
C(1,8) = (1.00-ETAA)*(1.00+ZTAA)*(27.00*XSII**2+9.00*ETAA**2+	ST4 1470
1 18.00*XSII-10.00)	ST4 1480
C(1,9) = (1.00-3.00*ETAA)*(1.00-ZTAA)*(9.00*ETAA**2-9.00)	ST4 1490
C(1,10) = (1.00+3.00*ETAA)*(1.00-ZTAA)*(9.00*ETAA**2-9.00)	ST4 1500
C(1,11) = -C(1,9)	ST4 1510
C(1,12) = -C(1,10)	ST4 1520
C(1,13) = (1.00-3.00*ETAA)*(1.00+ZTAA)*(9.00*ETAA**2-9.00)	ST4 1530

C(1,14)=(1.00+3.00*ETAA)*(1.00+ZTAA)*(9.00*ETAA**2-9.00)	ST4 1540
C(1,15)=-C(1,13)	ST4 1550
C(1,16)=-C(1,14)	ST4 1560
C(1,17)=(1.00+ETAA)*(1.00-ZTAA)*(10.00+18.00*XSII-27.00*XSII**2-9.00*ETAA**2)	ST4 1570
1	ST4 1580
C(1,18)=(1.00+ETAA)*(1.00-ZTAA)*(81.00*XSII**2-18.00*XSII-27.00)	ST4 1590
C(1,19)=(1.00+ETAA)*(1.00-ZTAA)*(27.00-18.00*XSII-81.00*XSII**2)	ST4 1600
C(1,20)=(1.00+ETAA)*(1.00-ZTAA)*(27.00*XSII**2+9.00*ETAA**2+18.00*XSII-10.00)	ST4 1610
1	ST4 1620
C(1,21)=(1.00+ETAA)*(1.00+ZTAA)*(10.00+18.00*XSII-27.00*XSII**2-9.00*ETAA**2)	ST4 1630
1	ST4 1640
C(1,22)=(1.00+ETAA)*(1.00+ZTAA)*(81.00*XSII**2-18.00*XSII-27.00)	ST4 1650
C(1,23)=(1.00+ETAA)*(1.00+ZTAA)*(27.00-18.00*XSII-81.00*XSII**2)	ST4 1660
C(1,24)=(1.00+ETAA)*(1.00+ZTAA)*(27.00*XSII**2+9.00*ETAA**2+18.00*XSII-10.00)	ST4 1670
1	ST4 1680
C(2,1)=(1.00-XSII)*(1.00-ZTAA)*(10.00+18.00*ETAA-9.00*XSII**2-27.00*ETAA**2)	ST4 1690
1	ST4 1700
C(2,2)=(1.00-3.00*XSII)*(1.00-ZTAA)*(9.00*XSII**2-9.00)	ST4 1710
C(2,3)=(1.00+3.00*XSII)*(1.00-ZTAA)*(9.00*XSII**2-9.00)	ST4 1720
C(2,4)=(1.00+XSII)*(1.00-ZTAA)*(10.00+18.00*ETAA-9.00*XSII**2-27.00*ETAA**2)	ST4 1730
1	ST4 1740
C(2,5)=(1.00-XSII)*(1.00+ZTAA)*(10.00+18.00*ETAA-9.00*XSII**2-27.00*ETAA**2)	ST4 1750
1	ST4 1760
C(2,6)=(1.00-3.00*XSII)*(1.00+ZTAA)*(9.00*XSII**2-9.00)	ST4 1770
C(2,7)=(1.00+3.00*XSII)*(1.00+ZTAA)*(9.00*XSII**2-9.00)	ST4 1780
C(2,8)=(1.00+XSII)*(1.00+ZTAA)*(10.00+18.00*ETAA-9.00*XSII**2-27.00*ETAA**2)	ST4 1790
1	ST4 1800
C(2,9)=(1.00-XSII)*(1.00-ZTAA)*(81.00*ETAA**2-18.00*ETAA-27.00)	ST4 1810
C(2,10)=(1.00-XSII)*(1.00-ZTAA)*(27.00-18.00*ETAA-81.00*ETAA**2)	ST4 1820
C(2,11)=(1.00+XSII)*(1.00-ZTAA)*(81.00*ETAA**2-18.00*ETAA-27.00)	ST4 1830
C(2,12)=(1.00+XSII)*(1.00-ZTAA)*(27.00-18.00*ETAA-81.00*ETAA**2)	ST4 1840
C(2,13)=(1.00-XSII)*(1.00+ZTAA)*(81.00*ETAA**2-18.00*ETAA-27.00)	ST4 1850
C(2,14)=(1.00-XSII)*(1.00+ZTAA)*(27.00-18.00*ETAA-81.00*ETAA**2)	ST4 1860
C(2,15)=(1.00+XSII)*(1.00+ZTAA)*(81.00*ETAA**2-18.00*ETAA-27.00)	ST4 1870
C(2,16)=(1.00+XSII)*(1.00+ZTAA)*(27.00-18.00*ETAA-81.00*ETAA**2)	ST4 1880
C(2,17)=(1.00-XSII)*(1.00-ZTAA)*(27.00*ETAA**2+9.00*XSII**2+18.00*ETAA-10.00)	ST4 1890
1	ST4 1900
C(2,18)=-C(2,2)	ST4 1910
C(2,19)=-C(2,3)	ST4 1920
C(2,20)=(1.00+XSII)*(1.00-ZTAA)*(27.00*ETAA**2+9.00*XSII**2+18.00*ETAA-10.00)	ST4 1930
1	ST4 1940
C(2,21)=(1.00-XSII)*(1.00+ZTAA)*(27.00*ETAA**2+9.00*XSII**2+18.00*ETAA-10.00)	ST4 1950
1	ST4 1960
C(2,22)=(1.00-3.00*XSII)*(1.00+ZTAA)*(9.00-9.00*XSII**2)	ST4 1970
C(2,23)=(1.00+3.00*XSII)*(1.00+ZTAA)*(9.00-9.00*XSII**2)	ST4 1980
C(2,24)=(1.00+XSII)*(1.00+ZTAA)*(27.00*ETAA**2+9.00*XSII**2+18.00*ETAA-10.00)	ST4 1990
1	ST4 2000
C(3,1)=(1.00-XSII)*(1.00-ETAA)*(10.00-9.00*XSII**2-9.00*ETAA**2)	ST4 2010
C(3,2)=(1.00-3.00*XSII)*(1.00-ETAA)*(9.00*XSII**2-9.00)	ST4 2020
C(3,3)=(1.00+3.00*XSII)*(1.00-ETAA)*(9.00*XSII**2-9.00)	ST4 2030
C(3,4)=(1.00+XSII)*(1.00-ETAA)*(9.00*XSII**2-9.00*ETAA**2)	ST4 2040

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DO 26 N=1,4
26 C(3,N+4) = -C(3,N)
C(3,9) = (1.00-3.00*ETAA)*(1.00-XSII)*(9.00*ETAA**2-9.00)
C(3,10) = (1.00+3.00*ETAA)*(1.00-XSII)*(9.00*ETAA**2-9.00)
C(3,11) = (1.00-3.00*ETAA)*(1.00+XSII)*(9.00*ETAA**2-9.00)
C(3,12) = (1.00+3.00*ETAA)*(1.00+XSII)*(9.00*ETAA**2-9.00)
DO 27 N=9,12
27 C(3,N+4) = -C(3,N)
C(3,17) = (1.00-XSII)*(1.00+ETAA)*(10.00-9.00*XSII**2-9.00*ETAA**2)
C(3,18) = (1.00-3.00*XSII)*(1.00+ETAA)*(9.00*XSII**2-9.00)
C(3,19) = (1.00+3.00*XSII)*(1.00+ETAA)*(9.00*XSII**2-9.00)
C(3,20) = (1.00+XSII)*(1.00+ETAA)*(10.00-9.00*XSII**2-9.00*ETAA**2)
DO 28 N=17,20
28 C(3,N+4) = -C(3,N)
DO 30 II=1,3
DO 30 KK=1,3
DJ(II, KK) = 0.00
DO 30 JJ=1,24
30 DJ(II, KK) = DJ(II, KK) + C(II, JJ) * XYZ(JJ, KK) / 64.00
C
FORM INVERSE J MATRIX DJI(3X3)
C
DETJ = DJ(1,1)*DJ(2,2)*DJ(3,3) - DJ(2,3)*DJ(3,2)
1 +DJ(1,2)*DJ(2,1)*DJ(3,3) - DJ(2,1)*DJ(3,3)
2 +DJ(1,3)*DJ(3,2)*DJ(2,1) - DJ(1,2)*DJ(3,1)
DJI(1,1) = (DJ(2,2)*DJ(3,3) - DJ(2,3)*DJ(3,2)) / DETJ
DJI(1,2) = (DJ(1,2)*DJ(3,3) - DJ(1,3)*DJ(3,2)) / DETJ
DJI(1,3) = (DJ(1,1)*DJ(2,3) - DJ(1,3)*DJ(2,2)) / DETJ
DJI(2,1) = (DJ(2,3)*DJ(3,1) - DJ(2,1)*DJ(3,3)) / DETJ
DJI(2,2) = (DJ(3,3)*DJ(1,1) - DJ(3,1)*DJ(1,3)) / DETJ
DJI(2,3) = (DJ(1,3)*DJ(2,1) - DJ(1,1)*DJ(2,3)) / DETJ
DJI(3,1) = (DJ(2,1)*DJ(3,2) - DJ(2,2)*DJ(3,1)) / DETJ
DO 40 I=1,6
C
FORM MATRIX B(6X72), WHERE (B) = (PA)
C
DJI(3,3) = (DJ(1,1)*DJ(2,2) - DJ(1,2)*DJ(2,1)) / DETJ
DJI(3,2) = (DJ(3,1)*DJ(1,2) - DJ(3,2)*DJ(1,1)) / DETJ
DO 40 L=1,72
40 BA(1,L) = 0.00
DO 50 N=1,70,3
L = (N - 1)/3 + 1
BA(1,N) = (DJI(1,1)*C(1,L)+DJI(1,2)*C(2,L)+DJI(1,3)*C(3,L))/64.00
BA(4,N) = (DJI(2,1)*C(1,L)+DJI(2,2)*C(2,L)+DJI(2,3)*C(3,L))/64.00
50 BA(5,N) = (DJI(3,1)*C(1,L)+DJI(3,2)*C(2,L)+DJI(3,3)*C(3,L))/64.00
DO 60 N=2,71,3
L = (N - 2)/3 + 1
BA(2,N) = (DJI(2,1)*C(1,L)+DJI(2,2)*C(2,L)+DJI(2,3)*C(3,L))/64.00
BA(4,N) = (DJI(1,1)*C(1,L)+DJI(1,2)*C(2,L)+DJI(1,3)*C(3,L))/64.00
60 BA(6,N) = (DJI(3,1)*C(1,L)+DJI(3,2)*C(2,L)+DJI(3,3)*C(3,L))/64.00
DO 70 N=3,72,3

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ST4 2050
ST4 2060
ST4 2070
ST4 2080
ST4 2090
ST4 2100
ST4 2110
ST4 2120
ST4 2130
ST4 2140
ST4 2150
ST4 2160
ST4 2170
ST4 2180
ST4 2190
ST4 2200
ST4 2210
ST4 2220
ST4 2230
ST4 2240
ST4 2250
ST4 2260
ST4 2270
ST4 2280
ST4 2290
ST4 2300
ST4 2310
ST4 2320
ST4 2330
ST4 2340
ST4 2350
ST4 2360
ST4 2370
ST4 2380
ST4 2390
ST4 2400
ST4 2410
ST4 2420
ST4 2430
ST4 2440
ST4 2450
ST4 2460
ST4 2470
ST4 2480
ST4 2490
ST4 2500
ST4 2510
ST4 2520
ST4 2530
ST4 2540
ST4 2550

```

```

      L = (N - 3)/3 + 1
      BA(3,N) = (DJI(3,1)*C(1,L)+DJI(3,2)*C(2,L)+DJI(3,3)*C(3,L))/64.00
      BA(5,N) = (DJI(1,1)*C(1,L)+DJI(1,2)*C(2,L)+DJI(1,3)*C(3,L))/64.00
70  BA(6,N) = (DJI(2,1)*C(1,L)+DJI(2,2)*C(2,L)+DJI(2,3)*C(3,L))/64.00
C
C   FIND ELASTIC MATRIX AND FORM TRIPLE MATRIX PRODUCT
C
      IF(ILNP.EQ.1.OR.IX(INEL,27).EQ.2.OR.IX(INEL,27).EQ.4)
1      CALL ELASTR
      DO 80 N=1,6
      DO 80 L=1,72
      BDB(N,L) = 0.00
      DO 80 NN=1,6
80  BDB(N,L) = BDB(N,L) + C(N,NN)*BA(NN,L)
      DO 90 I=1,6
      DO 90 J=1,72
90  SIG(I)=SIG(I) + BDB(I,J)*UEL(J)
C
C   INCLUDE THERMAL AFFECTS
C
      TMP = TMPND(IX(INEL,ILNP)) - AMBTMP
      DO 92 I=1,6
      DO 92 J=1,6
92  SIG(I) = SIG(I) - D(I,J)*ALFTMP(J) * TMP
      IF(ISTR5.EQ.1.OR.ISTR5.EQ.3) GO TO 96
C   PRINT STRESSES IN RECTANGULAR COORDINATES
      IF(LINE.LT.48) GO TO 94
      CALL TITLE
      WRITE(LIST,2000)
94  CONTINUE
      IF(ILNP.EQ.1) GO TO 95
      WRITE(LIST,2001) IX(INEL,ILNP), (SIG(I),I=1,6)
      IF(ISTR5.EQ.0) GO TO 100
      IF(ISTR5.EQ.4) GO TO 96
95  WRITE(LIST,2002) INEL, IX(INEL,ILNP), (SIG(I),I=1,6)
      IF(ISTR5.EQ.0) GO TO 100
C
C   TRANSFORM STRESSES TO CYLINDRICAL COORDINATES
C
96  SIGXY(1,1) = SIG(1)
      SIGXY(1,2) = SIG(4)/2.00
      SIGXY(1,3) = SIG(5)/2.00
      SIGXY(2,1) = SIG(4)/2.00
      SIGXY(2,2) = SIG(2)
      SIGXY(2,3) = SIG(6)/2.00
      SIGXY(3,1) = SIG(5)/2.00
      SIGXY(3,2) = SIG(6)/2.00
      SIGXY(3,3) = SIG(3)
      THEDA = 3.1415926535897900 * YT(IX(INEL,ILNP)) / 180.00
540 T(1,1) = DCOS(THEDA)
      T(1,2) = DSIN(THEDA)

```

ST4 2560
 ST4 2570
 ST4 2580
 ST4 2590
 ST4 2600
 ST4 2610
 ST4 2620
 ST4 2630
 ST4 2640
 ST4 2650
 ST4 2660
 ST4 2670
 ST4 2680
 ST4 2690
 ST4 2700
 ST4 2710
 ST4 2720
 ST4 2730
 ST4 2740
 ST4 2750
 ST4 2760
 ST4 2770
 ST4 2780
 ST4 2790
 ST4 2800
 ST4 2810
 ST4 2820
 ST4 2830
 ST4 2840
 ST4 2850
 ST4 2860
 ST4 2870
 ST4 2880
 ST4 2890
 ST4 2900
 ST4 2910
 ST4 2920
 ST4 2930
 ST4 2940
 ST4 2950
 ST4 2960
 ST4 2970
 ST4 2980
 ST4 2990
 ST4 3000
 ST4 3010
 ST4 3020
 ST4 3030
 ST4 3040
 ST4 3050
 ST4 3060

T(1,J) = 0.00	ST4 3070
T(2,1) = -T(1,2)	ST4 3080
T(2,2) = T(1,1)	ST4 3090
T(2,3) = 0.00	ST4 3100
T(3,1) = 0.00	ST4 3110
T(3,2) = 0.00	ST4 3120
DO 537 II=1,3	ST4 3130
T(3,3) = 1.00	ST4 3140
DO 537 JJ=1,3	ST4 3150
537 SIGRTH(II,JJ) = 0.00	ST4 3160
DO 538 II=1,3	ST4 3170
DO 538 JJ=1,3	ST4 3180
DO 538 KK=1,3	ST4 3190
DO 538 LL=1,3	ST4 3200
IF(DABS(T(II,KK)) .LT. 1.0-16) T(II,KK) = 0.00	ST4 3210
538 SIGRTH(II,JJ) = SIGRTH(II,JJ) + T(II,KK)*T(JJ,LL)*SIGXY(KK,LL)	ST4 3220
SIG(1) = SIGRTH(1,1)	ST4 3230
SIG(2) = SIGRTH(2,2)	ST4 3240
SIG(3) = SIGRTH(3,3)	ST4 3250
SIG(4) = SIGRTH(1,2)*2.00	ST4 3260
SIG(5) = SIGRTH(1,3)*2.00	ST4 3270
SIG(6) = SIGRTH(2,3)*2.00	ST4 3280
C	ST4 3290
C PRINT STRESSES IN CYLINDRICAL COORDINATES	ST4 3300
C	ST4 3310
IF(ISTRS .NE. 4) GO TO 539	ST4 3320
DO 98 ISIG=1,6	ST4 3330
98 SIGSAV(ISIG,ILNP) = SIG(ISIG)	ST4 3340
IF(ILNP .LT. 24) GO TO 100	ST4 3350
WRITE(LIST,2003)	ST4 3360
WRITE(LIST,2005) INEL, IX(INEL,1), (SIGSAV(I,1),I=1,6)	ST4 3370
WRITE(LIST,2004) (IX(INEL,J), (SIGSAV(I,J),I=1,6),J=2,24)	ST4 3380
LINE = LINE + 24	ST4 3390
539 IF (LINE.LT.48) GO TO 97	ST4 3400
CALL TITLE	ST4 3410
WRITE (LIST,2003)	ST4 3420
97 CONTINUE	ST4 3430
IF(ILNP .EQ. 1) GO TO 99	ST4 3440
WRITE (LIST,2004) IX(INEL,ILNP), (SIG(I),I=1,6)	ST4 3450
GO TO 100	ST4 3460
99 WRITE(LIST,2005)INEL,IX(INEL,ILNP),(SIG(I),I=1,6)	ST4 3470
100 CONTINUE	ST4 3480
LINE = LINE + 1	ST4 3490
200 CONTINUE	ST4 3500
300 CONTINUE	ST4 3510
RETURN	ST4 3520
END	ST4 3530

	SUBROUTINE ELASTR	EL4	10
C		EL4	20
C	* * * * *	* EL4	30
C	* * * * *	* EL4	40
C	* SUBROUTINE ELASTR, IN CONJUNCTION WITH DMATST, CALCULATES THE	* EL4	50
C	* ELASTIC MATRIX FOR EACH ELEMENT	* EL4	60
C	* * * * *	* EL4	70
C	* THIS SUBROUTINE IS CALLED BY -	* EL4	80
C	* STRESS	* EL4	90
C	* * * * *	* EL4	100
C	* THIS SUBROUTINE CALLS -	* EL4	110
C	* DMATST	* EL4	120
C	* * * * *	* EL4	130
C	* * * * *	* EL4	140
C		EL4	150
	IMPLICIT REAL*8 (A-H,O-Z)	EL4	160
	INTEGER*2 IX, MTLND	EL4	170
	COMMON / GENLS / NEL, NGLOF, NGNP, NMTL, INEL, ILNP, IGNP, INTL	EL4	180
	COMMON / MATL / E(9,9,10), D(6,6), FIBORT(9), ALFA1(9),	EL4	190
	1 ALFA2(9), ALFA3(9), AMETMP, ETM(9), TMPEL(9,10), NTMP(9)	EL4	200
	COMMON / NODAL / X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	EL4	210
	1 UZ(1015), TMPND(1015), U(3045), ALFTMP(6), XT(1015), YT(1015),	EL4	220
	2 ISTRS, IX(144,27), MTLND(1015)	EL4	230
	IF(IX(INEL,27) .EQ. 1 .OR. IX(INEL,27) .EQ. 3) GO TO 31	EL4	240
	IF(IX(INEL,27) .EQ. 2) GO TO 2	EL4	250
	NTMP1 = NTMP(IX(INEL,25))	EL4	260
	IF(NTMP1 .EQ. 1) GO TO 31	EL4	270
	INTL = MTLND(IX(INEL,ILNP))	EL4	280
	IF(INTL .EQ. 0) INTL = IX(INEL,25)	EL4	290
	IGNT = IX(INEL,ILNP)	EL4	300
	IF(TMPND(IGNT) .LT. TMPEL(INTL,1)) GO TO 5	EL4	310
	IF(TMPND(IGNT) .GE. TMPEL(INTL,NTMP(INTL))) GO TO 6	EL4	320
	NTMPM1 = NTMP(INTL) - 1	EL4	330
	DO 20 II=1,NTMPM1	EL4	340
	IF(TMPND(IGNT).GT. TMPEL(INTL,II) .AND. TMPND(IGNT).LE.	EL4	350
	1 TMPEL(INTL,II+1)) GO TO 4	EL4	360
	20 CONTINUE	EL4	370
	WRITE(6,6001)	EL4	380
6001	FORMAT(' ERROR 1')	EL4	390
	5 DO 30 I=1,9	EL4	400
	30 EIM(I) = E(INTL,I,1)	EL4	410
	GO TO 1	EL4	420
	6 DO 40 I=1,9	EL4	430
	40 ETM(I) = E(INTL,I,NTMP(INTL))	EL4	440
	GO TO 1	EL4	450
	4 DIFT1 = TMPEL(INTL,II+1) - TMPEL(INTL,II)	EL4	460
	DIFT2 = TMPND(IGNT) - TMPEL(INTL,II)	EL4	470
	RATIOF = DIFT2 / DIFT1	EL4	480
	DO 50 I=1,9	EL4	490
50	ETM(I) = E(INTL,I,II) + RATIOF * (E(INTL,I,II+1) - E(INTL,I,II))	EL4	500
	GO TO 1	EL4	510


```

31 IMTL = IX(INEL,25)
   DO 60 I=1,9
60 ETM(I) = E(IMTL,I,1)
   GO TO 1
   2 IMTL = MTLND(IX(INEL,ILNP))
   IF(IMTL.EQ.0) IMTL = IX(INEL,25)
   DO 80 I=1,9
80 ETM(I) = E(IMTL,I,1)
   1 CALL DMATST
   RETURN
   END

```

```

EL4 520
EL4 530
EL4 540
EL4 550
EL4 560
EL4 570
EL4 580
EL4 590
EL4 600
EL4 610
EL4 620

```

	SUBROUTINE DMATST	DM4	10
C		DM4	20
C	*****	DM4	30
C	*	DM4	40
C	* SUBROUTINE DMATST CALCULATES THE ELASTIC MATRIX AND PERFORMS A	DM4	50
C	* ROTATIONAL TRANSFORMATION ON THE ELASTIC MATRIX	DM4	60
C	*	DM4	70
C	* THIS SUBROUTINE IS CALLED BY -	DM4	80
C	* ELASTR	DM4	90
C	*	DM4	100
C	*****	DM4	110
C		DM4	120
	IMPLICIT REAL*8 (A-H,O-Z)	DM4	130
	INTEGER*2 IX, MTLND	DM4	140
	COMMON / GENLS / NEL, NCLDF, NGNP, NMTL, INEL, ILNP, IGNP, IMTL	DM4	150
	COMMON / MATL / E(9,9,10), D(6,6), FIBORT(9), ALFA1(9),	DM4	160
	1 ALFA2(9), ALFA3(9), AMBTMP, ETM(9), TMPEL(9,10), NTMP(9)	DM4	170
	COMMON / MODAL / X(1015), Y(1015), Z(1015), UX(1015), UY(1015),	DM4	180
	1 UZ(1015), TMPND(1015), U(3045), ALFTMP(6), XT(1015), YT(1015),	DM4	190
	2 ISTRS, IX(144,27), MTLND(1015)	DM4	200
	DIMENSION T(6,6), TD(6,6), TT(6,6), TMPCOF(6), DTMP(6,6)	DM4	210
	DO 10 I=1,6	DM4	220
	DO 10 J=1,6	DM4	230
	T(I,J) = 0.00	DM4	240
	U(I,J) = 0.00	DM4	250
	10 TD(I,J) = 0.00	DM4	260
	XNU21 = ETM(4) * ETM(2) / ETM(1)	DM4	270
	XNU31 = ETM(5) * ETM(3) / ETM(1)	DM4	280
	XNU32 = ETM(6) * ETM(3) / ETM(2)	DM4	290
	FACT=1.00-ETM(4)*(XNU21+ETM(6)*XNU31)-ETM(5)*(XNU31+XNU32*XNU21)-	DM4	300
	1 ETM(6)*XNU32	DM4	310
	D(1,1) = ETM(1) * (1.00 - ETM(6) * XNU32) / FACT	DM4	320
	D(1,2) = ETM(2) * (ETM(4) + ETM(5) * XNU32) / FACT	DM4	330
	D(1,3) = ETM(3) * (ETM(5) + ETM(4) * ETM(6)) / FACT	DM4	340
	D(2,1) = D(1,2)	DM4	350
	D(2,2) = ETM(2) * (1.00 - ETM(5) * XNU31) / FACT	DM4	360
	D(2,3) = ETM(3) * (ETM(6) + ETM(5) * XNU21) / FACT	DM4	370
	D(3,1) = D(1,3)	DM4	380
	D(3,2) = D(2,3)	DM4	390
	D(3,3) = ETM(3) * (1.00 - ETM(4) * XNU21) / FACT	DM4	400
	U(4,4) = ETM(7)	DM4	410
	D(5,5) = ETM(8)	DM4	420
	U(6,6) = ETM(9)	DM4	430
	ALFTMP(1) = ALFA1(IMTL)	DM4	440
	ALFTMP(2) = ALFA2(IMTL)	DM4	450
	ALFTMP(3) = ALFA3(IMTL)	DM4	460
	DO 60 I=4,6	DM4	470
	60 ALFTMP(I) = 0.00	DM4	480
	IF(DABS(FIBORT(IMTL)) .LT. .5D-14) GO TO 50	DM4	490
	FIBOR = FIBORT(IMTL) * 3.1415926535897932DC / 180.00	DM4	500
	T(1,1) = DCOS(FIBOR)**2	DM4	510

T(1,2) = DSIN(FIBOR)**2	DM4 520
T(4,1) = DCOS(FIBOR) * DSIN(FIBOR)	DM4 530
T(1,4) = -2.00 * T(4,1)	DM4 540
T(2,1) = T(1,2)	DM4 550
T(2,2) = T(1,1)	DM4 560
T(2,4) = -T(1,4)	DM4 570
T(3,3) = 1.00	DM4 580
T(4,2) = -T(4,1)	DM4 590
T(4,4) = T(1,1) - T(1,2)	DM4 600
T(5,5) = DCOS(FIBOR)	DM4 610
T(6,5) = DSIN(FIBOR)	DM4 620
T(5,6) = -T(6,5)	DM4 630
T(6,6) = T(5,5)	DM4 640
DO 70 I=1,6	DM4 650
TMPCOF(I) = 0.00	DM4 660
DO 70 J=1,6	DM4 670
70 TMPCOF(I) = TMPCOF(I) + T(I,J) * ALFTMP(J)	DM4 680
DO 90 I=1,6	DM4 690
90 ALFTMP(I) = TMPCOF(I)	DM4 700
DO 20 I=1,6	DM4 710
DO 20 J=1,6	DM4 720
DO 20 K=1,6	DM4 730
20 TD(I,J) = TD(I,J) + T(I,K)*D(K,J)	DM4 740
DO 80 I=1,6	DM4 750
DO 80 J=1,6	DM4 760
80 TT(J,I) = T(I,J)	DM4 770
DO 30 I=1,6	DM4 780
DO 30 J=1,6	DM4 790
DTMP(I,J) = 0.00	DM4 800
DO 30 K=1,6	DM4 810
30 DTMP(I,J) = DTMP(I,J) + TD(I,K) * TT(K,J)	DM4 820
DO 40 I=1,6	DM4 830
DO 40 J=1,6	DM4 840
40 D(I,J) = DTMP(I,J)	DM4 850
50 CONTINUE	DM4 860
RETURN	DM4 870
END	DM4 880

APPENDIX B

Input/Output Units and Sample JCL

A. Introduction

One disk unit is required for job steps 2, 3 and 4. This unit is a direct access file with a minimum logical record length of 21024 bytes. This file is used to pass data from step 2 to step 3 and from step 3 to step 4. It is also used in the iterative loop in step 3.

A sequential disk or tape unit can be used to pass data from a mesh generator (step 1) to step 2. This sequential unit should be blocked for card images.

The sample JCL given in this Appendix is for the IBM 360/370 operating system.

JCL to run four job steps

```
JOB ORIGIN FROM LOCAL DEVICE=RD1 . ,200.
//R1225TS1 JOB F0803,DANA,MSGLEVEL=1
/*MAIN REGION=(200,292,230,248),TIME=(1,2,30,4),LINES=4
//STEP1 EXEC FORTGCG
//FORT.SYSIN DD *
/*
//GO.FTC1F001 DD DSN=&DATATEM,UNIT=SYSDA,
// SPACE=(TRK,(5,1),RLSE);
// DISP=(NEW,PASS,DELETE),
// LCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//GO.SYSIN DD *
/*
//STEP2 EXEC FORTGCG
//FORT.SYSLIN DD DSN=&LOADSET,DISP=(NEW,PASS),
// UNIT=SYSSQ,SPACE=(80,(200,150),RLSE),DCB=BLKSIZE=80
//FORT.SYSIN DD *
//GO.FTC1F001 DD DSN=&DATATEM,UNIT=SYSDA,
// DISP=(OLD,DELETE)
//GO.FTC3F001 DD DSN=&KEMTREC,UNIT=SYSDA,
// DISP=(NEW,PASS,DELETE),
// SPACE=(26000,(15,9),RLSE),
// DCB=(RECFM=FT,LRECL=26000,BLKSIZE=26000,BUFNO=1)
//GO.SYSIN DD *
/*
//STEP3 EXEC FORTGCG
//FORT.SYSIN DD *
/*
//GO.FT03F001 DD DSN=&KEMTREC,UNIT=SYSDA,
// DISP=(OLD,PASS,DELETE),
// SPACE=(26000,(15,9),RLSE),
// DCB=(RECFM=FT,LRECL=26000,BLKSIZE=26000,BUFNO=1)
//GO.SYSIN DD *
/*
//STEP4 EXEC FORTGCG
//FORT.SYSLIN DD DSN=&LOADSET,DISP=(NEW,PASS),
// UNIT=SYSSQ,SPACE=(80,(200,150),RLSE),DCB=BLKSIZE=80
//FORT.SYSIN DD *
/*
//GO.FT03F001 DD DSN=&KEMTREC,UNIT=SYSDA,
// SPACE=(26000,(15,9),RLSE),
// DISP=(OLD,DELETE,DELETE),
// DCB=(RECFM=FT,LRECL=26000,BLKSIZE=26000,BUFNO=1)
//GO.SYSIN DD *
/*
//
```

JCL to run steps 1 and 2

```
JOB ('RIG'N FROM LOCAL DEVICE=RL1      ,200.
//P1225T17 JOB F0803,DANA,MSGLEVEL=1
/*MAIN      REGION=(,200,292),TIME=(1,1,5),LIMITS=
// EXEC PGM=IEFBR14
//DD1 DD DISP=(OLD,DELETE),DSN=JUND.AFC803,UNIT=SYSDA,VOL=SER=USERPK
/*
//STEP1 EXEC FORTGCC
//FORT.SYSIN DD *
//GO.FT01F001 DD DSN=QDATATEM,UNIT=SYSDA,
//      SPACE=(TRK,(5,1),RLSE),
//      DISP=(NEW,PASS,DELETE),
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=600)
//GO.SYSIN DD *
/*
//STEP2 EXEC FORTGCC
//FORT.SYSIN DD DSN=QLOADSET,DISP=(NEW,PASS),
//      UNIT=SYSSQ,SPACE=(80,(200,150),RLSE),DCB=BLKSIZE=80
//FORT.SYSIN DD *
//GO.FT01F001 DD DSN=QDATATEM,UNIT=SYSDA,
//      DISP=(OLD,DELETE)
//GO.FT03F001 DD DSN=JUND.AFC803,UNIT=SYSDA,VOL=SER=USERPK,
//      DISP=(NEW,PASS,DELETE),
//      SPACE=(26000,(15,3),RLSE),
//      DCB=(RECFM=FT,LRECL=26000,BLKSIZE=26000,LUFNO=1)
//GO.SYSIN DD *
/*
```

JCL to run step 3

```
JOB ORIGIN FROM LOCAL DEVICE=RD1      ,20C.
//B1225T13 JOB FC803,DANA,MSGLEVEL=1
//*MAIN REGION=230,TIME=30,LINES=4
//STEP3 EXEC FORTGCG
//FORT.SYSIN DD *
/*
//GO.FT03FC01 DD DSN=JOND.AF0803,UNIT=SYSDA,VOL=SER=USERPK,
// DISP=(OLD,KEEP,KEEP),
// SPACE=(26000,(15,3),RLSE),
// DCB=(RECFM=FT,LRECL=26000,BLKSIZE=26000,BUFNO=1)
//GO.SYSIN DD *
/*
//
```

JCL to run Step 4

```
JOB ORIGIN FROM LOCAL DEVICE=RD1      ,20C.
//B1225T16 JOB FC803,DANA,MSGLEVEL=1
//STEP4 EXEC FORTGCG
//FORT.SYSLIN DD DSN=&LOADSET,DISP=(NEW,PASS),
// UNIT=SYSSQ,SPACE=(80,(200,150),RLSE),DCB=BLKSIZE=80
//FORT.SYSIN DD *
/*
//GO.FT03FC01 DD DSN=JOND.AF0803,UNIT=SYSDA,VOL=SER=USERPK,
// DISP=(OLD,KEEP,KEEP),
// SPACE=(26000,(15,3),RLSE),
// SPACE=(26000,(15,3),RLSE),
// DCB=(RECFM=FT,LRECL=26000,BLKSIZE=26000,BUFNO=1)
//GO.SYSIN DD *
/*
//
```

APPENDIX C

Rectangular Plate Mesh Generator

A. Introduction

This mesh generator will yield element, nodal, material, and temperature distribution data necessary to idealize a rectangular solid laminate subjected to plate bending loads or axial extension in the x, y or z-directions. Force and displacement boundary conditions for each node are generated by specifying the boundary condition codes and values at a point, along a line or on a plane. From one to six elements can be specified in the x- or y-directions and from one to ten elements can be specified in the z-direction. Figure C-1 shows a typical mesh.

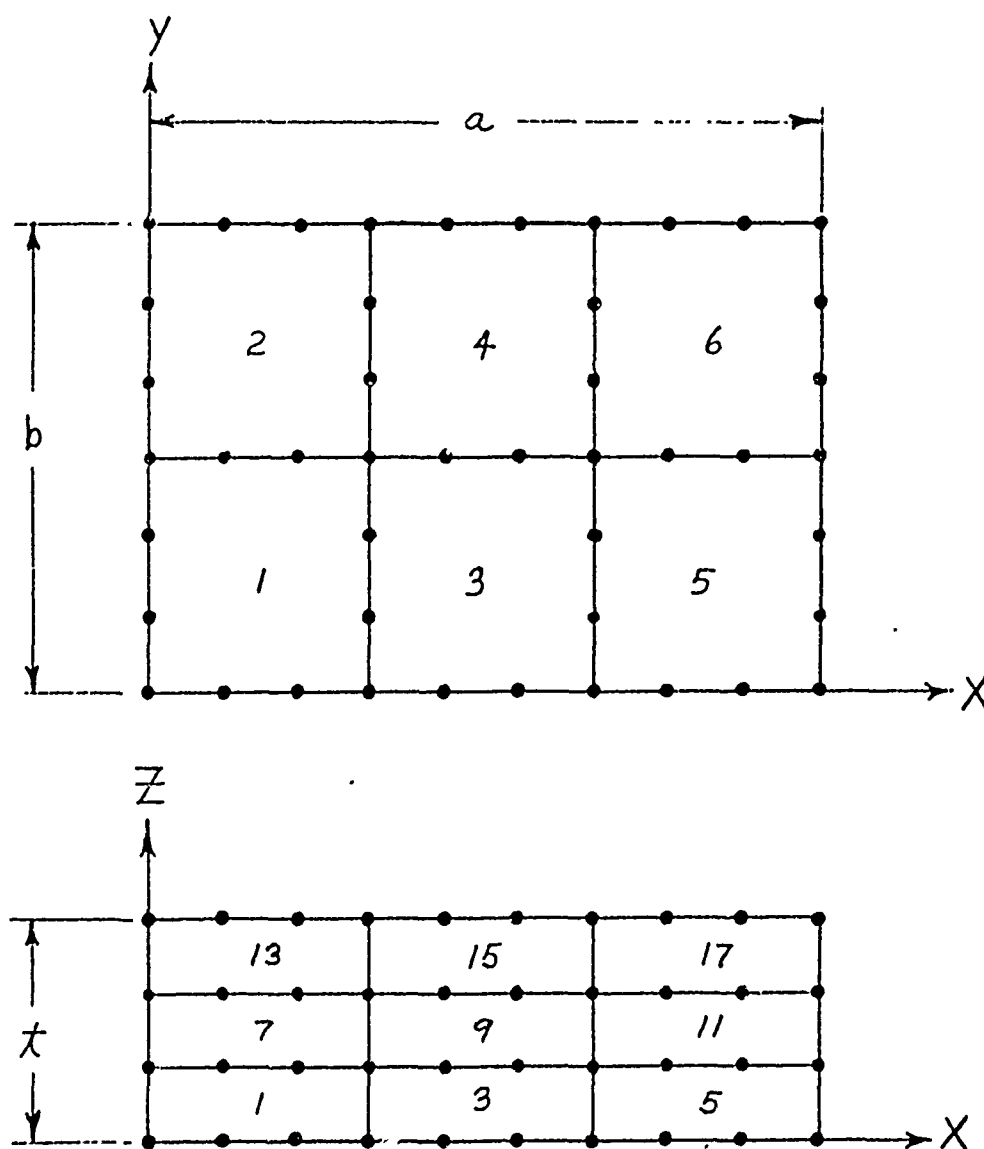


FIGURE C-1: Mesh for Rectangular Plate

B. Input Data

1. Heading Card (10A8)

Columns 1-80 information to be printed with output

2. Output unit card (16I5)

Columns 1-5 unit number (specifies the unit for passing data to the next job step, e.g. unit seven if data is to be punched on cards)

3. Control parameters cards two cards

First card (2I5, F10.2)

Columns 1-5 type of thermal-elastic problem (called classes)

'1' - elastic only, constant material properties within an element

'2' - elastic only, material properties can vary within an element

'3' - thermal elastic, material properties cannot vary with temperature within an element

'4' - thermal elastic, material properties can vary with temperature within an element

(Class 1 or 2 elements cannot be mixed with Class 3 or 4 elements. Classes 1 and 2 can be mixed and classes 3 and 4 can be mixed.)

6-10 type of temperature distribution

'0' - constant temperature

'1' - one dimensional variation, x-direction

'2' - one dimensional variation, y-direction

'3' - one dimensional variation, z-direction

'4' - two dimensional variation, x-y plane

'5' - two dimensional variation, x-z plane

'6' - two dimensional variation, y-z plane

'7' - three dimensional variation (not used)

11-20 initial temperature

Second card (I10, 2F10.5) blank card if class 1 or 2.

Columns 1-10 maximum number of iterations for finding temperature distribution

11-20 initial guess for temperature distribution

21-30 accuracy of temperature distribution

4. Plate and mesh dimensions card (3(I5, F10.0)) one card

Columns 1-5 number of elements in the x-direction ('1' to '6')

6-15 x-dimension of plate, a

16-20 number of elements in the y-direction ('1' to '6')

21-30 y-dimension of plate, b

31-35 number of elements in the z-direction ('1' to '6')

36-45 z-dimension of plate, t

5. Material change data cards (16I5)

Columns 1-5 number of materials

5-10 number of material changes

11-15 material number

16-20 element number at which the material changed

(Use as many sets of material number and element number as required to describe at which element a material is changed. The elements are numbered, on the plate, first in the y-direction, then the x-direction and then in the z-direction.)

6. Material data cards two cards

First card (2I5, 7F10.0) one for each material

Columns 1-5 material number (in sequential order)

6-10 number of material cards

('1' for class 1, 2 or 3)

11-20 fiber orientation in degrees

21-30 thermal expansion coefficient, α_{11}

31-40 thermal expansion coefficient, α_{22}

41-50 thermal expansion coefficient, α_{33}

Subsequent cards (F5.0, 3F10.0, 3F5.2, 3F10.0) (One card for problem class 1, 2 or 3. And for problem class 4, one

card for each temperature for which material properties are specified.)

Columns 1-5 temperature for material properties

(can be left blank for class 1 and 2 problems)

6-15 modulus of elasticity, E_{11} , KSI

16-25 modulus of elasticity, E_{22} , KSI

26-35 modulus of elasticity, E_{33} , KSI

36-40 Poisson's ratio, ν_{12}

41-45 Poisson's ratio, ν_{13}

46-50 Poisson's ratio, ν_{23}

51-60 shear modulus, G_{12} KSI

61-70 shear modulus, G_{13} KSI

71-80 shear modulus, G_{23} KSI

7. Element change data cards (16I5)

Columns 1-5 number of unique elements

6-10 number of element changes

11-15 element type number

16-20 element number at which the element type changes

(Use as many sets of element type and element number as required to describe at which element number an element type is changed.)

8. z-direction load coefficients (8F10.0) one card (leave blank if no loads in the z-direction)

The load in the z-direction is evaluated from the following expression.

$$P = C_1 + C_2x + C_3y + C_4x^2 + C_5y^2 + C_6xy \\ + C_7 \left(\sin \frac{\pi x}{A} \right) \left(\sin \frac{\pi y}{B} \right) + C_8 \left(\sin \frac{\pi x}{2A} \right) \left(\sin \frac{\pi y}{2B} \right)$$

Where:

Columns 1-10 C_1 , constant coefficient

11-20 C_2 , coefficient for linear variation in the x-direction

- 21-30 C_3 , coefficient for linear variation in the y-direction
- 31-40 C_4 , coefficient for quadratic variation in the x-direction
- 41-50 C_5 , coefficient for quadratic variation in the y-direction
- 51-60 C_6 , coefficient for product variation in x and y directions
- 61-70 C_7 , coefficient for full sine function in x and y directions
- 71-80 C_8 , coefficient for half sine function in x and y directions

9. Temperature boundary conditions (8F10.0) one card

(Leave blank for class 1 or 2)

- Columns 1-10 temperature at corner 1 $(x, y, z) = (0, 0, 0)$
- 11-20 temperature at corner 2 $(x, y, z) = (a, 0, 0)$
- 21-30 temperature at corner 3 $(x, y, z) = (0, b, 0)$
- 31-40 temperature at corner 4 $(x, y, z) = (a, b, 0)$
- 41-50 temperature at corner 5 $(x, y, z) = (0, 0, t)$
- 51-60 temperature at corner 6 $(x, y, z) = (a, 0, t)$
- 61-70 temperature at corner 7 $(x, y, z) = (0, b, t)$
- 71-80 temperature at corner 8 $(x, y, z) = (a, b, t)$

10. Material properties at nodes

First Card (4I5, 3F10.0) blank card for class 1, 3 or 4

Columns 1-5 number of material property cards

Second Card (4I5, 3F10.0) no cards for class 1, 3 or 4

Columns 1-5 material number

6-10 index coordinate, x-direction

11-15 index coordinate, y-direction

16-20 index coordinate, z-direction

11. Force/displacement boundary conditions (4I5, 3F10.0)

Columns 1-5 boundary condition code

6-10 index coordinate, x-direction
11-15 index coordinate, y-direction
16-20 index coordinate, z-direction
21-30 magnitude of x-direction boundary condition
31-40 magnitude of y-direction boundary condition
41-50 magnitude of z-direction boundary condition

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C      MAIN PROGRAM STEP 1A                                MGP 10
C                                                         MGP 20
C      * * * * *                                           MGP 30
C      *                                                         MGP 40
C      * THIS MESH GENERATOR IDEALIZES A RECTANGULAR LAMINATED PLATE * MGP 50
C      *                                                         MGP 60
C      * * * * *                                           MGP 70
C                                                         MGP 80
C      IMPLICIT REAL*8 (A-H,O-Z)                           MGP 90
C      INTEGER*2 IX, ICOD, IDPIX1, MTLND                   MGP 100
C      COMMON /GENMAT/ X(1066),Y(1066),Z(1066),UX(1066),UY(1066),UZ(1066) MGP 110
C      1 , TMPND(1066), BCIMP(8),                          MGP 120
C      2 ALFA1(10),ALFA2(10),ALFA3(10),FIBORT(10),E(10,9,10),TMPEL(10,10),MGP 130
C      3 NTMP(10),IX(144,27),ICOD(1066),IDPIX1(19,19,11),MTLND(1066) MGP 140
C      COMMON / GENL1 / TMPINT, EPSTMP, AX, BY, CZ, THELLX,THELLY,ELLZ,MGP 150
C      1 NEL, NGNP, NGLDF, NMTL, NTYEL, LMTMP, NELX, NELY, NELZ, ICLASSMGP 160
C      2 , ITYTD, NELX31, NELY31, NELZ1                     MGP 170
C      COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE         MGP 180
C      1000 FORMAT( 16I5)                                     MGP 190
C      1001 FORMAT(2I5, F10.2, 3F10.0)                       MGP 200
C      1002 FORMAT(F5.0, 3F10.0, 3F5.2, 3F10.0)             MGP 210
C      1003 FORMAT( 14, 14, 12, 6F10.0, F10.2)              MGP 220
C      1004 FORMAT( 10A8)                                     MGP 230
C      1005 FORMAT( 4I5, F10.2)                               MGP 240
C      1011 FORMAT(I10, 2F10.5)                               MGP 250
C      ICRD = 5                                               MGP 260
C      IPAGE = 1                                              MGP 270
C      IWRT = 6                                               MGP 280
C      READ(5,1004) HED                                       MGP 290
C      READ(5,1000) NTUT                                       MGP 300
C      READ(5,1001) ICLASS, ITYTD, AMBTMP                     MGP 310
C      READ(5,1011) LMTMP, TMPINT, EPSTMP                     MGP 320
C                                                         MGP 330
C      GENERATE MESH AND BOUNDARY CONDITIONS                  MGP 340
C                                                         MGP 350
C      CALL MSHGEN                                             MGP 360
C      CALL BCGEN                                             MGP 370
C      DO 20 I=1,NGNP                                         MGP 380
C      20 TMPND(I) = AMBTMP                                    MGP 390
C      IF ( ICLASS .LE. 2 ) GO TO 1                           MGP 400
C      CALL TMPDST                                             MGP 410
C      1 CONTINUE                                             MGP 420
C      CALL DISPLY                                             MGP 430
C      CALL MODF                                              MGP 440
C                                                         MGP 450
C      WRITE MESH DATA ON UNIT NTUT                           MGP 460
C                                                         MGP 470
C      WRITE(NTUT,1004) HED                                    MGP 480
C      WRITE(NTUT,1005) NGNP, NMTL, NEL, NTYEL, AMBTMP       MGP 490
C      DO 10 IMTL=1,NMTL                                       MGP 500
C      WRITE(NTUT,1001) IMTL, NTMP(IMTL), FIBORT(IMTL), ALFA1(IMTL), MGP 510

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1	ALFA2(IMTL), ALFA3(IMTL)	MGP	520
	NTMP1 = NTMP(IMTL)	MGP	530
	DO 10 ITMP=1,NTMP1	MGP	540
10	WRITE(NTUT,1002) IMPEL(IMTL,ITMP), (E(IMTL,J,ITMP),J=1,9)	MGP	550
	DO 30 INEL=1,NEL	MGP	560
30	WRITE(NTUT,1000) INEL, (IX(INEL,J),J=1,27)	MGP	570
	DO 40 M=1,NGNP	MGP	580
40	WRITE(NTUT,1003) M, MTLND(M), ICODE(M), X(M), Y(M), Z(M),	MGP	590
	1 UX(M), UY(M), UZ(M), TMPND(M)	MGP	600
	IF(NTUT .NE. 7) REWIND NTUT	MGP	610
	STOP	MGP	620
	END	MGP	630

	SUBROUTINE	MSHGEN	MSP	
C			10	
C			MSP	20
C	*	*****	* MSP	30
C	*		* MSP	40
C	*	SUBROUTINE MSHGEN GENERATES THE MESH AND NUMBERS NODES AND	* MSP	50
C	*	ELEMENTS	* MSP	60
C	*		* MSP	70
C	*	*****	* MSP	80
C			MSP	90
	IMPLICIT REAL*8 (A-H,O-Z)		MSP	100
	INTEGER*2 IX, ICODE, IDPIX1, MTLND		MSP	110
	COMMON /GENMAT/ X(1066),Y(1066),Z(1066),UX(1066),UY(1066),UZ(1066)		MSP	120
	1 , TMPND(1066), BCTMP(8),		MSP	130
	2 ALFA1(10),ALFA2(10),ALFA3(10),FIBORT(10),E(10,9,10),TMPEL(10,10),		MSP	140
	3 NTMP(10),IX(144,27),ICODE(1066),IDPIX1(19,19,11),MTLND(1066)		MSP	150
	COMMON / GENL1 / TMPINT, EPSTMP, AX, BY, CZ, THELLX,THFLY,ELLZ,MSP		MSP	160
	1 NEL, NGNP, NGLOF, NMIL, NTYEL, LMTMP, NELX, NELY, NELZ, ICLASSMSP		MSP	170
	2 , ITYTO, NELX31, NELY31, NELZ1		MSP	180
	COMMON / CORD / RUNX, RUNY, RUNZ, IRUNX, IRUNY, IRUNZ, IST		MSP	190
	COMMON /DATDIS/ XCRD(19), YCRD(19), ZCRD(11)		MSP	200
	COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE		MSP	210
	DIMENSION IMATL(10), IXMLCH(10), ITYEL(10), IXELCH(10)		MSP	220
	DIMENSION INEWX(16), IRECX(8), IPSSX(8)		MSP	230
	DIMENSION INEWZ1(12), IRECY(12), IPSSY(4), IRECY(4),		MSP	240
	1 INEWZ3(8), IPSSXZ(4), IRECXZ(4)		MSP	250
	DIMENSION ISG1(3), ISG2(3), ISG3(3), ISG4(3)		MSP	260
	DIMENSION LNCRD(12), ISTCDX(12), ISTCDY(12)		MSP	270
	DATA INEWX/ 2,3,4,6,7,8,11,12,15,16,18,19,20,22,23,24 /		MSP	280
	DATA IRECX/ 1,5,9,10,13,14,17,21 /		MSP	290
	DATA IPSSX/ 4,8,11,12,15,16,20,24 /		MSP	300
	DATA INEWZ1 / 5,6,7, 8, 13, 14, 15, 16, 21, 22, 23, 24 /		MSP	310
	DATA IRECY / 1, 2, 3, 4, 9, 10, 11, 12, 17, 18, 19, 20 /		MSP	320
	DATA IPSSY / 21, 22, 23, 24 /		MSP	330
	DATA IRECY / 5, 6, 7, 8 /		MSP	340
	DATA INEWZ3 / 6, 7, 8, 15, 16, 22, 23, 24 /		MSP	350
	DATA IPSSXZ / 8, 15, 16, 24 /		MSP	360
	DATA IRECXZ / 5, 13, 14, 21 /		MSP	370
	DATA ISG1, ISG2, ISG3, ISG4 /8,1,7,7,1,8,4,1,5,3,2,2/		MSP	380
	DATA LNCRD /5, 6, 7, 8, 13, 14, 15, 16, 21, 22, 23, 24 /		MSP	390
	DATA ISTCDX /0, 1, 1, 1, -3, 0, 3, 0, -3, 1, 1, 1 /		MSP	400
	DATA ISTCDY / 0, 0, 0, 0, 1, 1, -1, 1, 1, 0, 0, 0 /		MSP	410
	100 FORMAT(16I5)		MSP	420
	101 FORMAT(3(I5, F10.0))		MSP	430
	204 FORMAT('OPLATE DIMENSIONS', T40, 'X =', F9.3, ' Y =', F9.3,		MSP	440
	1 ' Z =', F9.3)		MSP	450
	205 FORMAT(' NUMBER OF ELEMENT', T40, 'XN =', I3, ' YN =', I3,		MSP	460
	1 ' ZN =', I3)		MSP	470
	206 FORMAT('MATERIAL TYPE AND MATERIAL CHANGES' /		MSP	480
	1 T10, 'MATERIAL TYPE CHANGE AT ELEMENT')		MSP	490
	306 FORMAT(18X, I2, 22X, I4)		MSP	500
	307 FORMAT('ELEMENT TYPE AND ELEMENT CHANGES' /		MSP	510

1	T10, 'ELEMENT TYPE	CHANGE AT ELEMENT'	MSP	520
1001	FORMAT(2I5, 7F10.0)		MSP	530
1002	FORMAT(F5.0, 3F10.0, 3F5.0, 3F10.0)		MSP	540
	READ(ICRD,101)	NELX, AX, NELY, BY, NELZ, CZ	MSP	550
	READ(ICRD,100)	NMTL, NMLCH, (IMATL(J),IXMLCH(J),J=1,NMLCH)	MSP	560
	DO 71 IMTL=1,NMTL		MSP	570
	READ(ICRD,1001)	MTLN, NTMP(IMTL), FIBORT(IMTL), ALFA1(IMTL),	MSP	580
1	ALFA2(IMTL), ALFA3(IMTL)		MSP	590
	NTMP1 = NTMP(IMTL)		MSP	600
	DO 71 ITMP=1,NTMP1		MSP	610
71	READ(ICRD,1002)	IMPLL(IMTL,ITMP), (E(IMTL,J,ITMP),J=1,9)	MSP	620
	READ(ICRD,100)	NTYEL, NELCH, (ITYEL(J),IXELCH(J),J=1,NELCH)	MSP	630
	CALL TITLE		MSP	640
	WRITE(IWRT,204)	AX, BY, CZ	MSP	650
	WRITE(IWRT,205)	NELX, NELY, NELZ	MSP	660
	WRITE(IWRT,206)		MSP	670
	WRITE(IWRT,306)	(IMATL(J), IXMLCH(J), J=1,NMLCH)	MSP	680
	WRITE(IWRT,307)		MSP	690
	WRITE(IWRT,306)	(ITYEL(J), IXELCH(J),J=1,NELCH)	MSP	700
	INEL = 0		MSP	710
	DO 1 IELY=1,NELY		MSP	720
	INEL = INEL+1		MSP	730
	IELY1= IELY-1		MSP	740
	DO 1 J=1,24		MSP	750
	IGNP = J+16*IELY1		MSP	760
1	IX(INEL,J) = IGNP		MSP	770
	IF(NELX.EQ.1) GO TO 6		MSP	780
	DO 5 IELX=2,NELX		MSP	790
	IGNPL = IGNP		MSP	800
	DO 3 IELY=1,NELY		MSP	810
	INEL = INEL + 1		MSP	820
	IMNY = INEL-NELY		MSP	830
	DO 2 J=1,8		MSP	840
2	IX(INEL,IRECX(J)) = IX(IMNY,IPSSX(J))		MSP	850
3	CONTINUE		MSP	860
	INEL = INEL- NELY		MSP	870
	DO 5 IELY=1,NELY		MSP	880
	INEL = INEL+1		MSP	890
	IELY1= IELY-1		MSP	900
	DO 4 J=1,16		MSP	910
	IGNP = IGNPL+J+10*IELY1		MSP	920
4	IX(INEL,INEX(J)) = IGNP		MSP	930
5	CONTINUE		MSP	940
6	CONTINUE		MSP	950
	IF(NELZ.EQ.1) GO TO 59		MSP	960
	DO 22 IFLZ = 2,NELZ		MSP	970
	INEL = INEL+1		MSP	980
	IMNZ = INEL-NELX*NELY		MSP	990
	DO 7 J=1,12		MSP	1000
7	IX(INEL,IRECZ(J)) = IX(IMNZ,INEXZ1(J))		MSP	1010
	DO 8 J=1,12		MSP	1020

IGNP = IGNU+1	MSP 1030
8 IX(INEL, INEWZ1(J)) = IGNU	MSP 1040
IF(NELY .EQ. 1) GO TO 66	MSP 1050
DO 12 IELY = 2, NELY	MSP 1060
INEL = INEL+1	MSP 1070
IMNZ = INEL-NELX*NELY	MSP 1080
DO 9 J=1,12	MSP 1090
9 IX(INEL, IRECZ(J)) = IX(IMNZ, INEWZ1(J))	MSP 1100
DO 10 J=1,4	MSP 1110
10 IX(INEL, IRECY(J)) = IX(INEL-1, IPSSY(J))	MSP 1120
DO 11 J=5,12	MSP 1130
IGNP = IGNU+1	MSP 1140
11 IX(INEL, INEWZ1(J)) = IGNU	MSP 1150
12 CONTINUE	MSP 1160
66 CONTINUE	MSP 1170
IF(NELX .EQ. 1) GO TO 22	MSP 1180
DO 21 IELX = 2, NELX	MSP 1190
INEL = INEL+1	MSP 1200
IMNZ = INEL-NELX*NELY	MSP 1210
DO 13 J=1,12	MSP 1220
13 IX(INEL, IRECZ(J)) = IX(IMNZ, INEWZ1(J))	MSP 1230
IMNX = INEL-NELY	MSP 1240
DO 14 J=1,4	MSP 1250
14 IX(INEL, IRECXZ(J)) = IX(IMNX, IPSSXZ(J))	MSP 1260
DO 15 J=1,8	MSP 1270
IGNP = IGNU+1	MSP 1280
15 IX(INEL, INEWZ3(J)) = IGNU	MSP 1290
IF(NELY .EQ. 1) GO TO 21	MSP 1300
DO 20 IELY = 2, NELY	MSP 1310
INEL = INEL+1	MSP 1320
IMNZ = INEL-NELX*NELY	MSP 1330
IMNX = INEL-NELY	MSP 1340
DO 16 J=1,12	MSP 1350
16 IX(INEL, IRECZ(J)) = IX(IMNZ, INEWZ1(J))	MSP 1360
DO 17 J=1,4	MSP 1370
17 IX(INEL, IRECXZ(J)) = IX(IMNX, IPSSXZ(J))	MSP 1380
DO 18 J=2,4	MSP 1390
18 IX(INEL, IRECY(J)) = IX(INEL-1, IPSSY(J))	MSP 1400
DO 19 J=4,8	MSP 1410
IGNP = IGNU+1	MSP 1420
19 IX(INEL, INEWZ3(J)) = IGNU	MSP 1430
20 CONTINUE	MSP 1440
21 CONTINUE	MSP 1450
22 CONTINUE	MSP 1460
59 NEL = INEL	MSP 1470
IXELCH(NELCH+1) = 0	MSP 1480
IXMLCH(NMLCH+1) = 0	MSP 1490
I = 0	MSP 1500
J = 0	MSP 1510
DO 23 INEL=1, NEL	MSP 1520
IF(INEL .EQ. IXMLCH(I+1)) I=I+1	MSP 1530

IF(INEL.EQ. IXELCH(J+1)) J=J+1	MSP 1540
IX(INEL,25) = IMATL(1)	MSP 1550
IX(INEL,26) = IYEL(J)	MSP 1560
IX(INEL,27) = ICLASS	MSP 1570
23 CONTINUE	MSP 1580
ELLX = AX/NELX	MSP 1590
ELLY = BY/NELY	MSP 1600
ELLZ = CZ/NELZ	MSP 1610
THELLX = ELLX/3.	MSP 1620
THELLY = ELLY/3.	MSP 1630
IRUNX = 1	MSP 1640
NELX31 = NELX*3+1	MSP 1650
NELY31 = NELY*3+1	MSP 1660
NELZ1 = NELZ+1	MSP 1670
IRUNY = 1	MSP 1680
IRUNZ = 1	MSP 1690
RUNX = 000	MSP 1700
RUNY = 000	MSP 1710
RUNZ = ELLZ	MSP 1720
IGNP = 1	MSP 1730
IST = 4	MSP 1740
DO 24 I=1,NELX31	MSP 1750
DO 24 J=1,NELY31	MSP 1760
DO 24 K=1,NELZ1	MSP 1770
24 IDPIX1(I,J,K) = 0	MSP 1780
XCRD(1) = 0.0	MSP 1790
YCRD(1) = 0.0	MSP 1800
ZCPD(1) = 0.0	MSP 1810
DO 25 I=2,NELX31	MSP 1820
25 XCRD(I) = XCRD(I-1) + THELLX	MSP 1830
DO 26 I=2,NELY31	MSP 1840
26 YCRD(I) = YCRD(I-1) + THELLY	MSP 1850
DO 27 I=1,NELZ	MSP 1860
27 ZCRD(I+1) = ZCRD(I) + ELLZ	MSP 1870
DO 28 IELY=1,NELY	MSP 1880
DO 28 J=1,3	MSP 1890
CALL COORD(IGNP)	MSP 1900
IGNP = IGNP + ISG1(J)	MSP 1910
IRUNY = IRUNY+1	MSP 1920
28 RUNY = RUNY + THELLY	MSP 1930
CALL COORD(IGNP)	MSP 1940
DO 30 I=1,2	MSP 1950
IRUNX = IRUNX+1	MSP 1960
RUNX = RUNX + THELLX	MSP 1970
IGNP = 1+I	MSP 1980
IRUNY = 1	MSP 1990
RUNY = 000	MSP 2000
DO 29 IELY=1,NELY	MSP 2010
CALL COORD(IGNP)	MSP 2020
IGNP = IGNP + 16	MSP 2030
IRUNY = IRUNY+3	MSP 2040

29 RUNY = RUNY + ELLY	MSP 2050
CALL COORD(IGNP)	MSP 2060
30 CONTINUE	MSP 2070
IRUNX = IRUNX+1	MSP 2080
RUNX = RUNX + THELLX	MSP 2090
IGNP = 4	MSP 2100
IRUNY = 1	MSP 2110
RUNY = 000	MSP 2120
DO 31 IELY=1,NELY	MSP 2130
DO 31 J=1,3	MSP 2140
CALL COORD(IGNP)	MSP 2150
IGNP = IGNP + ISG2(J)	MSP 2160
IRUNY = IRUNY+1	MSP 2170
31 RUNY = RUNY + THELLY	MSP 2180
CALL COORD(IGNP)	MSP 2190
IGNP = IGNP + 1	MSP 2200
IST = 3	MSP 2210
IF(NELX.EQ. 1) GO TO 61	MSP 2220
DO 35 IELX=2,NELX	MSP 2230
IGNPL = IGNP+ 3	MSP 2240
DO 33 I=1,2	MSP 2250
IRUNX = IRUNX+1	MSP 2260
RUNX = RUNX + THELLX	MSP 2270
IGNP = IGNPL + I	MSP 2280
IRUNY = 1	MSP 2290
RUNY = 000	MSP 2300
DO 32 IELY=1,NELY	MSP 2310
CALL COORD(IGNP)	MSP 2320
IGNP = IGNP + 10	MSP 2330
IRUNY = IRUNY+3	MSP 2340
32 RUNY = RUNY + ELLY	MSP 2350
CALL COORD(IGNP)	MSP 2360
33 CONTINUE	MSP 2370
IRUNX = IRUNX+1	MSP 2380
RUNX = RUNX + THELLX	MSP 2390
IGNP = IGNPL + 3	MSP 2400
IRUNY = 1	MSP 2410
RUNY = 000	MSP 2420
DO 34 IELY=1,NELY	MSP 2430
DO 34 J=1,3	MSP 2440
IDPIX1(IRUNX,IRUNY,1) = IGNP	MSP 2450
IDPIX1(IRUNX,IRUNY,2)=IGNP+ISG4(J)	MSP 2460
X(IGNP) = RUNX.	MSP 2470
X(IGNP+ISG4(J)) = RUNX	MSP 2480
Y(IGNP) = RUNY	MSP 2490
Y(IGNP+ISG4(J)) = RUNY	MSP 2500
Z(IGNP) = 000	MSP 2510
Z(IGNP+ISG4(J)) = RUNZ	MSP 2520
IGNP = IGNP + ISG3(J)	MSP 2530
IRUNY = IRUNY+1	MSP 2540
34 RUNY = RUNY + THELLY	MSP 2550

35 CALL CO'RD(IGNP)	MSP 2560
61 CONTINUE	MSP 2570
INEL = N1'X*NELY	MSP 2580
IF(NELZ .LT. 2) GO TO 37	MSP 2590
DO 36 IELZ=2,NELZ	MSP 2600
IRUNX = 1	MSP 2610
IRUNZ = IELZ+1	MSP 2620
DO 36 IELX=1,NELX	MSP 2630
IRUNX = IRUNX + 3	MSP 2640
IRUNY = 1	MSP 2650
DO 36 IELY=1,NELY	MSP 2660
IRUNX = IRUNX-3	MSP 2670
INEL = INEL + 1	MSP 2680
IMNZ = INEL-NELY*NELX	MSP 2690
DO 36 J=1,12	MSP 2700
L = LNCRD(J)	MSP 2710
X(IX(INEL,L)) = X(IX(IMNZ,L))	MSP 2720
Y(IX(INEL,L)) = Y(IX(IMNZ,L))	MSP 2730
Z(IX(INEL,L)) = IELZ*ELLZ	MSP 2740
IRUNX = IRUNX + ISTCDX(J)	MSP 2750
IRUNY = IRUNY + ISTCDY(J)	MSP 2760
36 IDPIX1(IRUNX,IRUNY,IRUNZ) = IX(INEL,L)	MSP 2770
37 NELZ1 = NELZ+1	MSP 2780
NGNP = (IGNP + 3) * NELZ1/2	MSP 2790
DO 38 I=1,NGNP	MSP 2800
38 MTLND(I) = 0	MSP 2810
NGLOF = 3*NGNP	MSP 2820
RETURN	MSP 2830
END	MSP 2840

	SUBROUTINE	COORD(IGNP)		COP	10
C				COP	20
C	*	*****		COP	30
C	*			COP	40
C	*	SUBROUTINE COORD CALCULATES THE X,Y&Z-COORDINATES FOR EACH NODE*		COP	50
C	*			COP	60
C	*	*****		COP	70
C				COP	80
	IMPLICIT REAL*8 (A-H,O-Z)			COP	90
	INTEGER*2 IX, ICODE, IDPIX1, MTLND			COP	100
	COMMON /GENMAT/ X(1066),Y(1066),Z(1066),UX(1066),UY(1066),UZ(1066)			COP	110
	1 , TMPND(1066), BCTMP(8),			COP	120
	2 ALFA1(10),ALFA2(10),ALFA3(10),FIBURT(10),E(10,9,10),TMPEL(10,10),			COP	130
	3 NTMP(10),IX(144,27),ICODE(1066),IDPIX1(19,19,11),MTLND(1066)			COP	140
	COMMON /CORD / RUNX, RUNY, RUNZ, IRUNX, IRUNY, IRUNZ, IST			COP	150
	IDPIX1(IRUNX,IRUNY,1)=IGNP			COP	160
	IDPIX1(IRUNX,IRUNY,2)=IGNP+1ST			COP	170
	X(IGNP) = RUNX			COP	180
	X(IGNP+1ST)=RUNX			COP	190
	Y(IGNP) = RUNY			COP	200
	Y(IGNP+1ST)=RUNY			COP	210
	Z(IGNP) = ODO			COP	220
	Z(IGNP+1ST)=RUNZ			COP	230
	RETURN			COP	240
	END			COP	250

2ITUDE Z-MAGNITUDE')	BCP 520
217 FORMAT(15,T13,12,T23,12,T33,12,T41,G11.3,T55,G11.3,T69,G11.3)		BCP 530
218 FORMAT('OMATERIAL PROPERTIES AT NODES' /		BCP 540
1 ' MTLND X-INDEX Y-INDEX Z-INDEX ')		BCP 550
DU 75 I=1,78		BCP 560
75 VLDMAT(I) = RELVT(I)		BCP 570
READ(ICRD,102) ZLCOEF		BCP 580
READ(ICRD,102) BCTMP		BCP 590
READ(ICRD,103) NMTLCD		BCP 600
WRITE(IWRT,208) ZLCOEF(1)		BCP 610
WRITE(IWRT,209) ZLCOEF(2)		BCP 620
WRITE(IWRT,210) ZLCOEF(3)		BCP 630
WRITE(IWRT,211) ZLCOEF(4)		BCP 640
WRITE(IWRT,212) ZLCOEF(5)		BCP 650
WRITE(IWRT,213) ZLCOEF(6)		BCP 660
WRITE(IWRT,214) ZLCOEF(7)		BCP 670
WRITE(IWRT,215) ZLCOEF(8)		BCP 680
LU = 2		BCP 690
DO 42 I=1,NGNP		BCP 700
ICODE(I) = 0		BCP 710
UX(I) = 000		BCP 720
UY(I) = 000		BCP 730
UZ(I) = 000		BCP 740
42 P(I) = 000		BCP 750
NMNN1 = NEL-NELY*NELX+1		BCP 760
DO 45 INEL=NMNN1,NEL		BCP 770
DU 43 I=1,12		BCP 780
L = LDRLVT(I,LU)		BCP 790
T = X(IX(INEL,L))		BCP 800
S = Y(IX(INEL,L))		BCP 810
43 PBAR(I) = ZLCOEF(1) + ZLCOEF(2)*T + ZLCOEF(3)*S		BCP 820
1 + ZLCOEF(4)*T*T + ZLCOEF(5)*S*S + ZLCOEF(6)*T*S		BCP 830
2 +ZLCOEF(7)*DSIN(3.14159*T/AX) *DSIN(3.14159*S/BY)		BCP 840
3 + ZLCOEF(8) *DSIN(3.14159*T/(2*AX)) *DSIN(3.14159*S/(2*BY))		BCP 850
M = 0		BCP 860
DO 44 I=1,12		BCP 870
K = IX(INEL,LDRLVT(I,LU))		BCP 880
DO 44 J=1,12		BCP 890
L = IX(INEL,LDRLVT(J,LU))		BCP 900
M = M + 1		BCP 910
P(K) = P(K) + VLDMAT(M) * PBAR(J)		BCP 920
IF(1.EQ. J) GO TO 44		BCP 930
P(L) = P(L) + VLDMAT(M) * PBAR(I)		BCP 940
44 CONTINUE		BCP 950
45 CONTINUE		BCP 960
ELLY = BY/NELY		BCP 970
ELLX = AX/NELX		BCP 980
AB = ELLX*ELLY		BCP 990
DU 46 IGNP=1, NGNP		BCP 1000
46 UZ(IGNP)= AB *P(IGNP) / 100800.		BCP 1010
IF(NMTLCD.EQ. 0) GO TO 41		BCP 1020

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CALL TITLE
WRITE(IWRT,218)
CO 40 IMTLCD=1,NMTLCD
READ(ICRD,103) MCODE, IXC, IYC, IZC
WRITE(IWRT,217) MCODE, IXC, IYC, IZC
IF(IXC .NE. 0 ) GO TO 78
IXO = 1
IXF = 3*NELX+1
GO TO 79
78 IXO = IXC
IXF = IXC
79 IF(IYC .NE. 0 ) GO TO 80
IYO = 1
IYF = 3*NELY+1
GO TO 81
80 IYO = IYC
IYF = IYC
81 IF(IZC .NE. 0 ) GO TO 82
IZO = 1
IZF = NELZ+1
GO TO 83
82 IZO = IZC
IZF = IZC
83 CONTINUE
DO 86 I=IXO,IXF
DO 86 J=IYO,IYF
DO 86 K=IZO,IZF
IF(IDPIX1(1,J,K) .EQ. C ) GO TO 86
MTLND(IDPIX1(1,J,K)) = MCODE
86 CONTINUE
40 CONTINUE
41 CALL TITLE
WRITE(IWRT,216)
47 READ(ICRD,103,END=58)LCODE,IXC,IYC,IZC,DBCX,BCY,BCZ
WRITE(IWRT,217) LCODE, IXC, IYC, IZC, DBCX, DBCY, DBCZ
IF(IXC .NE. 0 ) GO TO 48
IXO = 1
IXF = 3*NELX+1
GO TO 49
48 IXO = IXC
IXF = IXC
49 IF(IYC .NE. 0 ) GO TO 50
IYO = 1
IYF = 3*NELY+1
GO TO 51
50 IYO = IYC
IYF = IYC
51 IF(IZC .NE. 0 ) GO TO 52
IZO = 1
IZF = NELZ+1
GO TO 53

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BCP 1030
BCP 1040
BCP 1050
BCP 1060
BCP 1070
BCP 1080
BCP 1090
BCP 1100
BCP 1110
BCP 1120
BCP 1130
BCP 1140
BCP 1150
BCP 1160
BCP 1170
BCP 1180
BCP 1190
BCP 1200
BCP 1210
BCP 1220
BCP 1230
BCP 1240
BCP 1250
BCP 1260
BCP 1270
BCP 1280
BCP 1290
BCP 1300
BCP 1310
BCP 1320
BCP 1330
BCP 1340
BCP 1350
BCP 1360
BCP 1370
BCP 1380
BCP 1390
BCP 1400
BCP 1410
BCP 1420
BCP 1430
BCP 1440
BCP 1450
BCP 1460
BCP 1470
BCP 1480
BCP 1490
BCP 1500
BCP 1510
BCP 1520
BCP 1530

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52 IZU = IZC	BCP 1540
IZF = IZC	BCP 1550
53 CONTINUE	BCP 1560
DO 56 I=IXO,IXF	BCP 1570
DO 56 J=IYU,IYF	BCP 1580
DO 56 K=IZO,IZF	BCP 1590
IF(IDPIX1(I,J,K) .EQ. 0) GO TO 56	BCP 1600
ICODE(IDPIX1(I,J,K)) = LCODE	BCP 1610
IF(LCODE .EQ. 0) GO TO 56	BCP 1620
IF(LCODE .EQ. 4 .OR. LCODE .EQ. 6) GO TO 54	BCP 1630
IF(LCODE .EQ. 5) GO TO 55	BCP 1640
UX(IDPIX1(I,J,K)) = DBCX	BCP 1650
IF(LCODE .EQ. 1) GO TO 56	BCP 1660
IF(LCODE .EQ. 3) GO TO 55	BCP 1670
54 UY(IDPIX1(I,J,K)) = DBCY	BCP 1680
IF(LCODE .EQ. 2 .OR. LCODE .EQ. 4) GO TO 56	BCP 1690
55 UZ(IDPIX1(I,J,K)) = DBCZ	BCP 1700
56 CONTINUE	BCP 1710
GO TO 47	BCP 1720
58 RETURN	BCP 1730
END	BCP 1740

40 DO 41 I=1,NELX	DIP 520
DO 41 L=1,NELY	DIP 530
M = M + 1	DIP 540
41 IDPIX1(3*I-1,3*L-1,NELZ+1)=IDPIX1(3*I ,3*L-1,NELZ)	DIP 550
NELX31 = NELX*3+1	DIP 560
NELY31 = NELY*3+1	DIP 570
IELZ = 0	DIP 580
11 NELX6 = NELX	DIP 590
ISW1 = 0	DIP 600
IELZ = IELZ+1	DIP 610
CALL TITLE	DIP 620
WRITE(IWRT,199) ZCRD(IELZ)	DIP 630
9 IF(NELX6 .GT. 6) GO TO 8	DIP 640
NELX36 = 3*NELX6+1	DIP 650
NELX16= NELX6+1	DIP 660
NELX26 = 2*NELX6+1	DIP 670
NELX62= 2*NELX6	DIP 680
NELX60 = NELX6	DIP 690
GO TO 12	DIP 700
8 NELX36 = 19	DIP 710
NELX16 = 7	DIP 720
NELX26 = 13	DIP 730
NELX62 = 12	DIP 740
NELX60 = 6	DIP 750
12 IF(ISW1 .EQ. 0) GO TO 13	DIP 760
N1 = 3*(NELX6+6)+1	DIP 770
DO 10 I=19,N1	DIP 780
XCRD(I-18) = XCRD(I)	DIP 790
DO 10 J=1,NELY31	DIP 800
10 IDPIX1(1-18,J,IELZ) = IDPIX1(I,J,IELZ)	DIP 810
13 ISW1 = 1	DIP 820
WRITE(IWRT,200) (XCRD(J),J=1,NELX36)	DIP 830
WRITE(IWRT,201) (VERTLN(J),J=1,NELX36)	DIP 840
WRITE(IWRT,201) (VERTLN(J),J=1,NELX36)	DIP 850
WRITE(IWRT,202) YCRD(NELY31) , (IDPIX1(J,NELY31,IELZ),J=1,NELX36)	DIP 860
DO 35 I=1,NELY	DIP 870
NELY31 = 3*(NELY-1)	DIP 880
WRITE(IWRT,203) (VERTLN(J),J=1,NELX16)	DIP 890
WRITE(IWRT,203) (VERTLN(J),J=1,NELX16)	DIP 900
M = 0	DIP 910
DO 45 L=1,NELX36,3	DIP 920
M = M+1	DIP 930
45 IDPL1(M) = IDPIX1(L,NELY31+3, IELZ)	DIP 940
WRITE(IWRT,204) YCRD(NELY31+3) , (IDPL1(J),ELEM1(J),J=1,NELX60),	DIP 950
1 IDPL1(NELX60+1)	DIP 960
WRITE(IWRT,205) (NUMB(J), VERTLN(J),J=1,NELX60)	DIP 970
WRITE(IWRT,203) (VERTLN(J),J=1,NELX16)	DIP 980
WRITE(IWRT,206) YCRD(NELY31+2) , (IDPIX1(J,NELY31+2,IELZ),	DIP 990
1 J=1,NELX36)	DIP 1000
WRITE(IWRT,203) (VERTLN(J),J=1,NELX16)	DIP 1010
WRITE(IWRT,203) (VERTLN(J),J=1,NELX16)	DIP 1020

35	WRITE(IWRT,202)YCRD(NELY3I+1),(IDPIX1(J,NELY3I+1,IELZ),J=1,NELX36)	DIP 1030
	NELX6 = NELX6-6	DIP 1040
	IF(NELX6 .LT. 1) GO TO 7	DIP 1050
	GO TO 9	DIP 1060
7	IF(IELZ .LE. NELZ) GO TO 11	DIP 1070
	RETURN	DIP 1080
	END	DIP 1090

	SUBROUTINE TITLE	TIP	10
C		TIP	20
C	* * * * *	TIP	30
C	*	TIP	40
C	* SUBROUTINE TITLE PRINTS THE HEADING ON EACH PAGE	TIP	50
C	*	TIP	60
C	* * * * *	TIP	70
C		TIP	80
	IMPLICIT REAL*8 (A-H,U-Z)	TIP	90
	COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE	TIP	100
100	FORMAT (1H1,'FEM 72-DUF GENERAL HEXAHEDRONS THERMO-ELASTIC, VARYINT	TIP	110
	16 MATERIAL PROPERTIES, DANA', 9X, 'PAGE', I3)	TIP	120
101	FORMAT (1H0,10A8)	TIP	130
	WRITE (IWRT,100) IPAGE	TIP	140
	WRITE (IWRT,101) HED	TIP	150
	IPAGE= IPAGE +1	TIP	160
	LINE = 0	TIP	170
	RETURN	TIP	180
	END	TIP	190

	SUBROUTINE TMPDST	TMP	10
C		TMP	20
C	* * * * *	TMP	30
C	*	TMP	40
C	* SUBROUTINE TMPDST SOLVES FOR ONE-DIMENSIONAL TEMPERATURE	TMP	50
C	* DISTRIBUTIONS	TMP	60
C	*	TMP	70
C	* * * * *	TMP	80
C		TMP	90
	IMPLICIT REAL*8 (A-H,O-Z)	TMP	100
	INTEGER*2 IX, ICODE, IDPIX1, MTLND	TMP	110
	COMMON /GENMAT/ X(1066),Y(1066),Z(1066),UX(1066),UY(1066),UZ(1066)	TMP	120
	1 , TMPND(1066), BCTMP(8),	TMP	130
	2 ALFA1(10),ALFA2(10),ALFA3(10),FIBORT(10),E(10,9,10),TMPEL(10,10),	TMP	140
	3 NTMP(10),IX(144,27),ICODE(1066),IDPIX1(19,19,11),MTLND(1066)	TMP	150
	COMMON / GENL1 / .TMPINT, EPSIMP, AX, BY, CZ, THELLX,THELLY,ELLZ,	TMP	160
	1 NEL, NGNP, NGLOF, NMIL, NTYEL, LMTMP, NELX, NELY, NELZ, ICLASSTMP	TMP	170
	2 , ITYTD, NELX31, NELY31, NELZ1	TMP	180
	COMMON / HEAD / HLD(10),ICRD,IWRT,IPAGE,LINE	TMP	190
	COMMON / TMPRTR/ TEMPI(19), TEMP2(19,19), TEMP3(19,19,11)	TMP	200
	200 FORMAT('O THE TEMPERATURE DISTRIBUTION IS CONSTANT AT',	TMP	210
	1 E15.7, ' DEGREES CENT.')	TMP	220
	201 FORMAT('O THE TEMPERATURE DISTRIBUTION VARIES FROM' , E15.7,	TMP	230
	1 ' TO', E15.7, ' IN THE X-DIRECTION ONLY')	TMP	240
	202 FORMAT('O THE TEMPERATURE DISTRIBUTION VARIES FROM' , E15.7,	TMP	250
	1 ' TO', E15.7, ' IN THE Y-DIRECTION ONLY')	TMP	260
	203 FORMAT('O THE TEMPERATURE DISTRIBUTION VARIES FROM' , E15.7,	TMP	270
	1 ' TO', E15.7, ' IN THE Z-DIRECTION ONLY')	TMP	280
	204 FORMAT('O TEMPERATURE DISTRIBUTION VARIES IN THE X-Y PLANE ONLY' /	TMP	290
	1 'O TEMPERATURE BC1 = ', E15.7/	TMP	300
	1 ' TEMPERATURE BC2 = ', E15.7/	TMP	310
	1 ' TEMPERATURE BC3 = ', E15.7/	TMP	320
	1 ' TEMPERATURE BC4 = ', E15.7)	TMP	330
	205 FORMAT('O TEMPERATURE DISTRIBUTION VARIES IN THE X-Z PLANE ONLY' /	TMP	340
	1 'O TEMPERATURE BC1 = ', E15.7/	TMP	350
	1 ' TEMPERATURE BC2 = ', E15.7/	TMP	360
	1 ' TEMPERATURE BC5 = ', E15.7/	TMP	370
	1 ' TEMPERATURE BC6 = ', E15.7)	TMP	380
	206 FORMAT('O TEMPERATURE DISTRIBUTION VARIES IN THE Y-Z PLANE ONLY' /	TMP	390
	1 'O TEMPERATURE BC1 = ', E15.7/	TMP	400
	1 ' TEMPERATURE BC3 = ', E15.7/	TMP	410
	1 ' TEMPERATURE BC5 = ', E15.7/	TMP	420
	1 ' TEMPERATURE BC7 = ', E15.7)	TMP	430
	207 FORMAT('O 3-D TEMPERATURE DISTRIBUTION SUBROUTINE NOT COMPLETE')	TMP	440
	IF (ITYTD.NE. 0) GO TO 10	TMP	450
	WRITE(IWRT,200) BCTMP(1)	TMP	460
	DO 20 I=1,NGNP	TMP	470
	20 TMPND(I) = BCTMP(1)	TMP	480
	GO TO 9	TMP	490
	10 NICM1X = NELX31 - 1	TMP	500
	NICMTY = NELY31 - 1	TMP	510

GO TO (1, 2, 3, 4, 5, 6, 7), ITRYD	TMP 520
1 TMPINC = (BCTMP(2) - BCTMP(1)) / NICMTX	TMP 530
WRITE(IWRT,201) BCTMP(1), BCTMP(2)	TMP 540
DO 21 I=1,NICMTX	TMP 550
21 TEMP1(I) = BCTMP(1) + TMPINC*(I-1)	TMP 560
TEMP1(NELX31) = BCTMP(2)	TMP 570
DO 31 I=1,NLLX31	TMP 580
DO 31 J=1,NELY31	TMP 590
DO 31 K=1,NELZ1	TMP 600
31 TEMP3(I,J,K) = TEMP1(I)	TMP 610
GO TO 8	TMP 620
2 TMPINC = (BCTMP(3) - BCTMP(1)) / NICMTY	TMP 630
WRITE(IWRT,202) BCTMP(1), BCTMP(3)	TMP 640
DO 22 J=1,NICMTY	TMP 650
22 TEMP1(J) = BCTMP(1) + TMPINC*(J-1)	TMP 660
TEMP1(NELY31) = BCTMP(3)	TMP 670
DO 32 I=1,NLLX31	TMP 680
DO 32 J=1,NELY31	TMP 690
DO 32 K=1,NELZ1	TMP 700
32 TEMP3(I,J,K) = TEMP1(J)	TMP 710
GO TO 8	TMP 720
3 TMPINC = (BCTMP(5) - BCTMP(1)) / NELZ	TMP 730
WRITE(IWRT,203) BCTMP(1), BCTMP(5)	TMP 740
DO 23 K=1,NLLZ	TMP 750
23 TEMP1(K) = BCTMP(1) + TMPINC*(K-1)	TMP 760
TEMP1(NELZ+1) = BCTMP(5)	TMP 770
DO 33 I=1,NLLX31	TMP 780
DO 33 J=1,NELY31	TMP 790
DO 33 K=1,NELZ1	TMP 800
33 TEMP3(I,J,K) = TEMP1(K)	TMP 810
GO TO 8	TMP 820
4 WRITE(IWRT,204) BCTMP(1), BCTMP(2), BCTMP(3), BCTMP(4)	TMP 830
BC1 =BCTMP(1)	TMP 840
BC2 =BCTMP(2)	TMP 850
BC3 =BCTMP(3)	TMP 860
BC4 =BCTMP(4)	TMP 870
CALL TWUD(THELLX, THELLY, NELX31, NELY31, BC1, BC2, BC3, BC4)	TMP 880
DO 34 I=1,NLLX31	TMP 890
DO 34 J=1,NELY31	TMP 900
DO 34 K=1,NELZ1	TMP 910
34 TEMP3(I,J,K) = TEMP2(I,J)	TMP 920
GO TO 8	TMP 930
5 WRITE(IWRT,205) BCTMP(1), BCTMP(2), BCTMP(5), BCTMP(6)	TMP 940
BC1 =BCTMP(1)	TMP 950
BC2 =BCTMP(2)	TMP 960
BC3 =BCTMP(5)	TMP 970
BC4 =BCTMP(6)	TMP 980
CALL TWUD(THELLX, ELLZ, NELX31, NELZ1, BC1, BC2, BC3, BC4)	TMP 990
DO 35 I=1,NELX31	TMP 1000
DO 35 J=1,NELY31	TMP 1010
DO 35 K=1,NELZ1	TMP 1020

35	TEMP3(I,J,K) = TEMP2(I,K)	TMP 1030
	GO TO 8	TMP 1040
6	WRITE(IWRT,206) BCTMP(1), BCTMP(3), BCTMP(5), BCTMP(7)	TMP 1050
	BC1 =BCTMP(1)	TMP 1060
	BC2 =BCTMP(3)	TMP 1070
	BC3 =BCTMP(5)	TMP 1080
	BC4 =BCTMP(7)	TMP 1090
	CALL TWOD(THELLY, ELLZ, NELY31, NELZ1 , BC1, BC2, BC3, BC4)	TMP 1100
	DO 36 I=1,NELX31	TMP 1110
	DO 36 J=1,NELY31	TMP 1120
	DO 36 K=1,NELZ1	TMP 1130
36	TEMP3(I,J,K) = TEMP2(J,K)	TMP 1140
	GO TO 8	TMP 1150
7	WRITE(IWRT,207)	TMP 1160
8	DO 40 I=1,NELX31	TMP 1170
	DO 40 J=1,NELY31	TMP 1180
	DO 40 K=1,NELZ1	TMP 1190
	IF(IDPIX1(I,J,K) .EQ. 0) GO TO 40	TMP 1200
	TEMPND(IDPIX1(I,J,K)) = TEMP3(I,J,K).	TMP 1210
40	CONTINUE	TMP 1220
9	RETURN	TMP 1230
	END	TMP 1240

C	SUBROUTINE TWOD(H1, H2, NPTS1, NPTS2, BC1, BC2, BC3, BC4)	TWP	10
C	*****	TWP	20
C	*****	TWP	30
C	* SUBROUTINE TWOD SOLVES FOR TWO-DIMENSIONAL TEMPERATURE	* TWP	40
C	* DISTRUBUTIONS	* TWP	50
C	*****	* TWP	60
C	*****	* TWP	70
C	*****	* TWP	80
C	*****	TWP	90
	IMPLICIT REAL*8 (A-H,O-Z)	TWP	100
	COMMON / GENLI / TMPINT, EPSTMP, AX, BY, CZ, THELLX,THELLY,ELLZ,TWP	TWP	110
	1 NEL, NGNP, NGLOF, NMTL, NYEL, LMTMP, NELX, NELY, NELZ, ICLASSTWP	TWP	120
	2 , ITYTD, NELX31, NELY31, NELZ1	TWP	130
	COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE	TWP	140
	COMMON / TMPRTR/ TEMP1(19), TEMP2(19,19), TEMP3(19,19,11)	TWP	150
	1000 FORMAT('0 TEMPERATURE DISTRIBUTION CONVERGED TO', E15.7,	TWP	160
	1 ' IN', I5, ' ITERATIONS')	TWP	170
	1001 FORMAT('0 TEMPERATURE DISTRIBUTION DID NOT CONVERGE TO',E15.7,	TWP	180
	1 ' IN', I5, ' ITERATIONS')	TWP	190
	NICMT1 = NPTS1 - 1	TWP	200
	NICMT2 = NPTS2 - 1	TWP	210
	DO 10 I=1,NPTS1	TWP	220
	DO 10 J=1,NPTS2	TWP	230
	10 TEMP2(I,J) = TMPINT	TWP	240
	TMPI NC = (BC2 - BC1) / NICMT1	TWP	250
	DO 11 I=2,NICMT1	TWP	260
	11 TEMP2(I,1) = BC1 + TMPI NC*(I-1)	TWP	270
	TMPI NC = (BC4 - BC3) / NICMT1	TWP	280
	DO 12 I=1,NICMT1	TWP	290
	12 TEMP2(1,NPTS2) = BC3 + TMPI NC*(I-1)	TWP	300
	TMPI NC = (BC3 - BC1) / NICMT2	TWP	310
	DO 13 J=1,NICMT2	TWP	320
	13 TEMP2(1,J) = BC1 + TMPI NC*(J-1)	TWP	330
	TMPI NC = (BC4 - BC2) / NICMT2	TWP	340
	DO 14 J=1,NICMT2	TWP	350
	14 TEMP2(NPTS1,J) = BC2 + TMPI NC*(J-1)	TWP	360
	TEMP2(NPTS1,NPTS2) = BC4	TWP	370
	NOCVT = 0	TWP	380
	KOUNT = 0	TWP	390
	H1SQ = H1*H1	TWP	400
	H2SQ = H2*H2	TWP	410
	DEM = 2.00 * (1.00/H1SQ + 1.00/H2SQ)	TWP	420
	1 IF(KOUNT .GT. LMTMP) GO TO 2	TWP	430
	ERRMAX = 0.00	TWP	440
	KOUNT = KOUNT + 1	TWP	450
	DO 20 I=2,NICMT1	TWP	460
	DO 20 J=2,NICMT2	TWP	470
	OLDTMP = TEMP2(I,J)	TWP	480
	TEMP2(I,J) = ((TEMP2(I-1,J) + TEMP2(I+1,J)) / H1SQ	TWP	490
	1 + ((TEMP2(I,J-1) + TEMP2(I,J+1)) / H2SQ) / DEM	TWP	500
	ERR = DABS(OLDTMP - TEMP2(I,J))	TWP	510

```

      IF( ERR .GT. ERRMAX ) ERRMAX = ERR
20  CONTINUE
      IF( ERRMAX .GT. EPSTMP ) GO TO 1
      WRITE(IWRT,1000) ERRMAX, KOUNT
      RETURN
2  WRITE(IWRT,1001) EPSTMP, KOUNT
      NOCVT = 1
      RETURN
      END

```

```

TWP 520
TWP 530
TWP 540
TWP 550
TWP 560
TWP 570
TWP 580
TWP 590
TWP 600

```

	SUBROUTINE MODF	MOP	10
C		MOP	20
C	* * * * *	MOP	30
C	*	MOP	40
C	* SUBROUTINE MODF DOES NOTHING — THIS SUBROUTINE CAN BE USED TO	MOP	50
C	* MODIFY ANY INFORMATION THAT HAS BEEN GENERATED	MOP	60
C	*	MOP	70
C	* * * * *	MOP	80
C		MOP	90
	IMPLICIT REAL*8 (A-H,O-Z)	MOP	100
	INTEGER*2 IX, ICODE, IDPIX1, MTLND	MOP	110
	COMMON /GENMAT/ X(1066),Y(1066),Z(1066),UX(1066),UY(1066),UZ(1066)	MOP	120
	1 , TMPND(1066), BCTMP(8),	MOP	130
	2 ALFA1(10),ALFA2(10),ALFA3(10),FIBORT(10),E(10,9,10),TMPEL(10,10),	MOP	140
	3 NTMP(10),IX(144,27),ICODE(1066),IDPIX1(19,19,11),MTLND(1066)	MOP	150
	COMMON / GFNL1 / TMPINT, EPSIMP, AX, BY, CZ, THELLX,THELLY,ELLZ,	MOP	160
	1 NEL, NGNP, NGLUF, NMTL, NTYEL, LMTMP, NELX, NELY, NELZ, ICLASS	MOP	170
	2 , IITY10, NELX31, NELY31, NELZ1	MOP	180
	COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE	MOP	190
	WRITE(IWRT,200)	MOP	200
200	FORMAT(// '0 DATA GENERATION STEP HAS NOT BEEN MODIFIED')	MOP	210
	RETURN	MOP	220
	END	MOP	230

APPENDIX D

Hole in Rectangular Plate Mesh Generator

A. Introduction

This mesh generator will yield element, nodal, and material data necessary to idealize a laminated composite pierced with a hole and subjected to axial and thermal loads. The shape of the hole can be circular, square or diamond. Loads are applied as a result of a uniform axial displacement in the x-direction at $x = \pm a$. The thermal effects are restricted to a constant temperature change. The mesh is restricted to the shape shown in Figure D-1 where a , b , t , c , e and R can be varied. The number of elements through-the-thickness is also a variable.

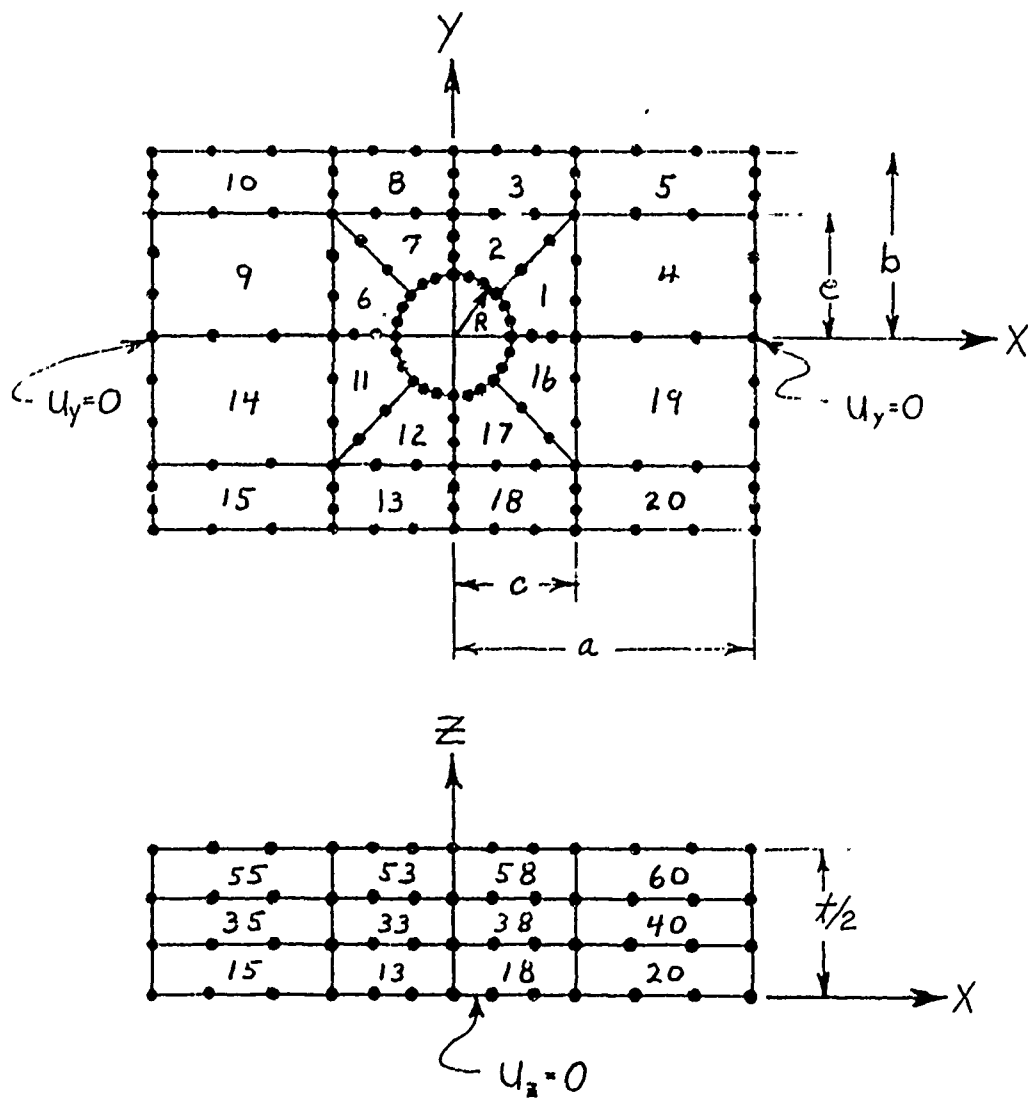


FIGURE D-1: Mesh for Rectangular Plate with a Hole

B. Input Data

1. Heading card (10A8)
Columns 1-80 information to be printed with output
2. Output unit card (I5) one card
Columns 1-5 unit number for passing data to next job step
3. Control and problem parameter card (I10, 2F10.0) one card
Columns 1-10 type of thermal-elastic problem
11-20 initial temperature
21-30 final temperatures
4. Plate and mesh dimensions cards two cards
First card (3 G10.0, I5)
Columns 1-10 a-dimension, inches
11-20 b-dimension, inches
21-30 t/2-dimension, inches
30-35 number of elements through the half thickness
Second card (3G10.1)
Columns 1-10 c-dimension, inches
11-20 e-dimension, inches
21-30 R-dimension, inches
5. Load and hole parameters (3I5, F10.0) one card
Columns 1-5 '0' if hole open, '1' if hole filled
6-10 '1' if circular hole
 '2' if square hole
 '3' if diamond hole
11-15 blank
16-26 magnitude of displacement, inches
6. Material change data cards (16I5)
Columns 1-5 number of materials
5-10 number of material changes
11-15 material number
16-20 element number at which the material changed
(Use as many sets of material number and element

number as required to describe at which element a material is changed. The elements are numbered, on the plate, as shown in Figure D-1.)

7. Material data cards two cards

First card (2I5, F10.2, 3F10.8) one for each material

Columns 1-5 material number (in sequential order)

6-10 number of material cards

('1' for class 1, 2 or 3)

11-20 fiber orientation in degrees

21-30 thermal expansion coefficient, α_{11}

31-40 thermal expansion coefficient, α_{22}

41-50 thermal expansion coefficient, α_{33}

Subsequent cards (F5.0, 3F10.0, 3F5.2, 3F10.0) (One card for problem class 1, 2 or 3. And for problem class 4, one card for each temperature for which material properties are specified.)

Columns 1-5 temperature for material properties

(can be left blank for class 1 and 2 problems)

6-15 modulus of elasticity, E_{11} , KSI

16-25 modulus of elasticity, E_{22} , KSI

26-35 modulus of elasticity, E_{33} , KSI

36-40 Poisson's ratio, ν_{12}

41-45 Poisson's ratio, ν_{13}

46-50 Poisson's ratio, ν_{23}

51-60 shear modulus, G_{12} , KSI

61-70 shear modulus, G_{13} , KSI

71-80 shear modulus, G_{23} , KSI

8. Element change data cards (16I5)

Columns 1-5 number of unique elements

6-10 number of element changes

11-15 element type number

16-20 element number at which the element type changes

(Use as many sets of element type and element number as required to describe at which element number an element type is changed.)

C	MAIN PROGRAM STEP 18	MGH	10
C		MGH	20
C	*****	MGH	30
C	*	MGH	40
C	* THIS MESH GENERATOR IDEALIZES A RECTANGULAR LAMINATED PLATE	MGH	50
C	* WITH A HOLE, LOADED IN UNIFORM EXTENSION IN THE X-DIRECTION	MGH	60
C	*	MGH	70
C	*****	MGH	80
C		MGH	90
	IMPLICIT REAL*8 (A-H,O-Z)	MGH	100
	INTEGER*2 IX, ICODE, IDPIX1, IMLND	MGH	110
	COMMON /GENMAT/ X(1015),Y(1015),Z(1015),UX(1015),UY(1015),UZ(1015)	MGH	120
	1 , TMPND(1015), BCTMP,	MGH	130
	2 ALFA1(10),ALFA2(10),ALFA3(10),FIBORT(10),E(10,9,10),TMPEL(10,10),	MGH	140
	3 NTMP(10),IX(144,27),ICUDE(1015),IDPIX1(19,19,11),IMLND(1015)	MGH	150
	COMMON / GENL1 / TMPINT, EPSTMP, AX, BY, CZ, THELLX,THELLY,ELLZ,MGH	MGH	160
	1 NEL, NGNP, NGLOF, NMTL, NTYEL, LMTMP, NELX, NELY, NELZ, ICLASS	MGH	170
	2 , ITYTD, NELX31, NELY31, NELZ1	MGH	180
	COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE	MGH	190
	1000 FORMAT(16I5)	MGH	200
	1001 FORMAT(2I5, F10.2, 3F10.8)	MGH	210
	1002 FORMAT(F5.0, 3F10.0, 3F5.2, 3F10.0)	MGH	220
	1003 FORMAT(I4, I4, I2, 6F10.0, F10.2)	MGH	230
	1004 FORMAT(10A8)	MGH	240
	1005 FORMAT(4I5, F10.2)	MGH	250
	1011 FORMAT(110, 2F10.5)	MGH	260
	ICRU = 5	MGH	270
	IPAGE = 1	MGH	280
	IWRT = 6	MGH	290
	READ(5,1004) HED	MGH	300
	READ(5,1000) NTUT	MGH	310
	READ(5,1011) ICLASS, AMRTMP, BCTMP	MGH	320
C		MGH	330
C	GENERATE MESH AND BOUNDARY CONDITIONS	MGH	340
C		MGH	350
	CALL DATGEN	MGH	360
	DO 20 I=1,NGNP	MGH	370
	20 TMPND(I) = BCTMP	MGH	380
	CALL MODF	MGH	390
C		MGH	400
C	WRITE MESH DATA ON UNIT NTUT	MGH	410
C		MGH	420
	WRITE(NTUT,1004) HED	MGH	430
	WRITE(NTUT,1005) NGNP, NMTL, NEL, NTYEL, AMBTMP	MGH	440
	DO 10 IMTL=1,NMTL	MGH	450
	WRITE(NTUT,1001) IMTL, NTMP(IMTL), FIBORT(IMTL), ALFA1(IMTL),	MGH	460
	1 ALFA2(IMTL), ALFA3(IMTL)	MGH	470
	NTMP1 = NTMP(IMTL)	MGH	480
	DO 10 ITMP=1,NTMP1	MGH	490
	10 WRITE(NTUT,1002) TMPEL(IMTL,ITMP), (E(IMTL,J,ITMP),J=1,9)	MGH	500
	DO 30 INEL=1,NEL	MGH	510

30 WRITE(NTUT,1000) INEL, (IX(INEL,J),J=1,27)	MGH 520
DO 40 M=1,NGNP	MGH 530
40 WRITE(NTUT,1003) M, MTLND(M), ICODE(M), X(M), Y(M), Z(M),	MGH 540
1 UX(M), UY(M), UZ(M), TNPND(M)	MGH 550
STOP	MGH 560
END	MGH 570

```

SUBROUTINE DATGEN
C
C *****
C * SUBROUTINE DATGEN GENERATES THE MESH, NUMBERS THE NODES AND
C * ELEMENTS, AND SPECIFIES BOUNDARY CONDITION CODES FOR EACH NODE
C *
C *****
C
IMPLICIT REAL*8 (A-H,O-Z)
INTEGER*2 IX, ICODE, IDPIX1, MTLND
COMMON /GENMAT/ X(1015),Y(1015),Z(1015),UX(1015),UY(1015),UZ(1015)
1 , TMPND(1015), BCTMP,
2 ALFA1(10),ALFA2(10),ALFA3(10),FIBORT(10),E(10,9,10),TMPEL(10,10),
3 NTMP(10),IX(144,27),ICODE(1015),IDPIX1(19,19,11),MTLND(1015)
COMMON / GENL1 / TMPIN1, EPSTMP, AX, BY, CZ, THELLX,THELLY,ELLZ,
1 NEL, NGNP, NGLDF, NMTL, NTYLL, LMTMP, NELX, NELY, NELZ, ICLASSDAH
Z , ITYTU, NELX31, NELY31, NELZ1
COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE
DIMENSION
1 IXFLCH(145), IXMLCH(145), IMATL(145), ITYEL(145)
DIMENSION IXDT1(24), IXDT2(24), IXDT3(24), IXDT4(24), IXDT5(24)
DIMENSION IXDT6(24), IXDT7(24), IXDT8(24), IXDT9(24), IXDT10(24)
DIMENSION JY11(24),IXDT12(24),IXDT13(24),IXDT14(24),IXDT15(24)
DIMENSION IXDT16(24),IXDT17(24),IXDT18(24),IXDT19(24),IXDT20(24)
DIMENSION IXDTP1(24), IXDTP2(24), IXDTP3(24), IXDTP4(24)
DIMENSION IPLNP1(10), IPLNP2(10), IPLNP3(10), IPLNP4(10)
DIMENSION IDX1(10), IDX2(10), IDX3(10), IDX4(10)
DIMENSION XLDSQ(4)
DATA IXDT1/ 1, 14, 18, 22, 137, 150, 154, 158, 2, 3, 23, 24, 138,
1 139, 159, 160, 4, 15, 19, 25, 140, 151, 155, 161 /
DATA IXDT2/ 7, 6, 5, 4, 143, 142, 141, 140, 8, 9, 15, 19, 144,
1 145, 151, 155, 10, 16, 20, 25, 146, 152, 156, 161 /
DATA IXDT3/ 10, 16, 20, 25, 146, 152, 156, 161, 11, 12, 26, 27,
1 147, 148, 162, 163, 13, 17, 21, 28, 149, 153, 157, 164 /
DATA IXDT4/ 22, 29, 32, 35, 158, 165, 168, 171, 23, 24, 36, 37,
1 159, 160, 172, 173, 25, 30, 33, 38, 161, 166, 169, 174 /
DATA IXDT5/ 25, 30, 33, 38, 161, 166, 169, 174, 26, 27, 39, 40,
1 162, 163, 175, 176, 28, 31, 34, 41, 164, 167, 170, 177 /
DATA IXDT6/ 56, 52, 48, 42, 192, 188, 184, 178, 57, 58, 43, 44,
1 193, 194, 179, 180, 59, 53, 49, 45, 195, 189, 185, 181 /
DATA IXDT7/ 45, 46, 47, 7, 181, 182, 183, 143, 49, 53, 8, 9,
1 185, 189, 144, 145, 59, 54, 50, 10, 195, 190, 186, 146 /
DATA IXDT8/ 59, 54, 50, 10, 195, 190, 186, 146, 60, 61, 11, 12,
1 196, 197, 147, 148, 62, 55, 51, 13, 198, 191, 187, 149 /
DATA IXDT9/ 69, 66, 63, 56, 205, 202, 199, 192, 70, 71, 57, 58,
1 206, 207, 193, 194, 72, 67, 64, 59, 208, 203, 200, 195 /
DATA IXDT10/ 72, 67, 64, 59, 208, 203, 200, 195, 73, 74, 60, 61,
1 209, 210, 196, 197, 75, 68, 65, 62, 211, 204, 201, 198 /
DATA IXDT11/ 96, 91, 88, 78, 232, 227, 224, 214, 95, 94, 77, 76,
1 231, 230, 213, 212, 56, 52, 48, 42, 192, 188, 184, 178 /

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DATA IXDT12/ 96, 92, 89, 84, 232, 228, 225, 220, 91, 88, 83, 82, DAH 520
1 227, 224, 219, 218, 78, 79, 80, 81, 214, 215, 216, 217 / DAH 530
DATA IXDT13/ 99, 93, 90, 87, 235, 229, 226, 223, 98, 97, 86, 85, DAH 540
1 234, 233, 222, 221, 96, 92, 89, 84, 232, 228, 225, 220 / DAH 550
DATA IXDT14/ 106, 102, 100, 96, 242, 238, 236, 232, 105, 104, 95, DAH 560
1 94, 241, 240, 231, 230, 69, 66, 63, 56, 205, 202, 199, 192 / DAH 570
DATA IXDT15/ 109, 103, 101, 99, 245, 239, 237, 235, 108, 107, 98, DAH 580
1 97, 244, 243, 234, 233, 106, 102, 100, 96, 242, 238, 236, 232 / DAH 590
DATA IXDT16/ 112, 115, 118, 123, 248, 251, 254, 259, 111, 110, DAH 600
1 122, 121, 247, 246, 258, 257, 1, 14, 18, 22, 137, 150, 154, 158/DAH 610
DATA IXDT17/ 84, 116, 119, 123, 220, 252, 255, 259, 83, 82, 118, DAH 620
1 115, 215, 218, 254, 251, 81, 114, 113, 112, 217, 250, 249, 248/ DAH 630
DATA IXDT18/ 87, 117, 120, 126, 223, 253, 256, 262, 86, 85, 125, DAH 640
1 124, 222, 221, 261, 260, 84, 116, 119, 123, 220, 252, 255, 259 /DAH 650
DATA IXDT19/ 123, 127, 129, 133, 259, 263, 265, 269, 122, 121,132,DAH 660
1 131, 258, 257, 268, 267, 22, 29, 32, 35, 158, 165, 168, 171 / DAH 670
DATA IXDT20/ 126, 128, 130, 136, 262, 264, 266, 272, 125, 124,135,DAH 680
1 134, 261, 260, 271, 270, 123, 127, 129, 133, 259, 263, 265, 269/DAH 690
DATA IXDTP1 / 0,0,0,1,0,0,0,137,0,0,2,3,0,0,138,139, DAH 700
1 7,6,5,4,143,142,141,140 / DAH 710
DATA IXDTP2 / 42,0,0,0,178,0,0,0,43,44,0,0,179,180,0,0, DAH 720
1 45,46,47,7,181,182,183,143 / DAH 730
DATA IXDTP3 / 78,79,80,81,214,215,216,217,77,76,0,0,213,212,0,0, DAH 740
1 42,0,0,0,178,0,0,0 / DAH 750
DATA IXDTP4 / 81,114,113,112,217,250,249,248,0,0,111,110,0,0,247, DAH 760
1 246,0,0,0,1,0,0,0,137 / DAH 770
DATA IDX1 / 1,2,3,5,6,7,9,10,13,14 / DAH 780
DATA IDX2 / 2,3,4,6,7,8,11,12,15,16 / DAH 790
DATA IDX3 / 11,12,15,16,18,19,20,22,23,24 / DAH 800
DATA IDX4 / 9,10,13,14,17,18,19,21,22,23 / DAH 810
DATA IPLNP1 / 3,4,5,12,13,14,7,6,16,15 / DAH 820
DATA IPLNP2 / 1,2,3,10,11,12,7,6,16,15 / DAH 830
DATA IPLNP3 / 9,8,18,17,1,2,3,10,11,12 / DAH 840
DATA IPLNP4 / 9,8,18,17,3,4,5,12,13,14 / DAH 850
DATA XLDSQ / 1.00, 3.00, 3.00, 1.00 / DAH 860
100 FORMAT(16I5) DAH 870
102 FORMAT( 3G10.0,I5) DAH 880
103 FORMAT(3G10.1) DAH 890
104 FORMAT(3I5, G10.0) DAH 900
202 FORMAT('LENGTH OF STRIP' ,T50,G24.7 / DAH 910
1 'WIDTH OF STRIP' ,T50,G24.7 / DAH 920
2 'THICKNESS OF STRIP' ,T50,G24.7 / DAH 930
3 'NUMBER OF ELEMENTS THICK' ,T50,G24.7 / DAH 940
4 'LENGTH OF INSERT' ,T50,G24.7 / DAH 950
5 'WIDTH OF INSERT' ,T50,G24.7 / DAH 960
6 'MAXIMUM WIDTH OF HOLE' ,T50,G24.7 / DAH 970
203 FORMAT('UNIFORM DISPLACEMENT IN INCHES OF ' , T50, G24.7) DAH 980
204 FORMAT('UNIFORM LOAD IN KIPS OF ' ,T50, G24.7) DAH 990
205 FORMAT('HOLE IS FILLED') DAH 1000
206 FORMAT('MATERIAL TYPE AND MATERIAL CHANGES' / DAH 1010
1 T10, 'MATERIAL TYPE CHANGE AT ELEMENT' ) DAH 1020

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207 FORMAT('CIRCULAR HOLE')	DAH 1030
208 FORMAT('OSQUARE HOLE')	DAH 1040
209 FORMAT('ODIAMOND HOLE')	DAH 1050
307 FORMAT('ELEMENT TYPE AND ELEMENT CHANGES' /	DAH 1060
1 T10, 'ELEMENT TYPE CHANGE AT ELEMENT')	DAH 1070
306 FORMAT(18X, 12, 22X, 14)	DAH 1080
1001 FORMAT(215, F10.2, 3F10.0)	DAH 1090
1002 FORMAT(F5.0, 3F10.0, 3F5.2, 3F10.0)	DAH 1100
READ(ICRD,102) XLNTH, YLNTH, ZLNTH, NELZ	DAH 1110
READ(ICRD,103) XINSRT, YINSRT, RADHL	DAH 1120
READ(ICRD,104) IFLHL, ITYHL, LDMD, DSPLD	DAH 1130
CALL TITLE	DAH 1140
XLNTH2 = 2.00 * XLNTH	DAH 1150
YLNTH2 = 2.00 * YLNTH	DAH 1160
ZLNTH2 = 2.00 * ZLNTH	DAH 1170
XINST2 = 2.00 * XINSRT	DAH 1180
YINST2 = 2.00 * YINSRT	DAH 1190
RADHL2 = 2.00 * RADHL	DAH 1200
WRITE(IWRT,202) XLNTH2,YLNTH2,ZLNTH2,NELZ, XINST2, YINST2, RADHL2	DAH 1210
IF(IFLHL .EQ. 1) WRITE(IWRT,205)	DAH 1220
GO TO (91, 92, 93), ITYHL	DAH 1230
91 WRITE(IWRT,207)	DAH 1240
GO TO 94	DAH 1250
92 WRITE(IWRT,208)	DAH 1260
GO TO 94	DAH 1270
93 WRITE(IWRT,209)	DAH 1280
94 IF(LDMD .EQ. 1) GO TO 95	DAH 1290
WRITE(IWRT,203) DSPLD	DAH 1300
GO TO 96	DAH 1310
95 WRITE(IWRT,204) DSPLD	DAH 1320
96 CONTINUE	DAH 1330
READ(ICRD,100) NMTL, NMLCH, (IMATL(J),IXMLCH(J),J=1,NMLCH)	DAH 1340
DO 71 IMTL=1,NMTL	DAH 1350
READ(ICRD,1001) HTLN, NTMP(IMTL), FIBORT(IMTL), ALFA1(IMTL),	DAH 1360
1 ALFA2(IMTL), ALFA3(IMTL)	DAH 1370
NTMP1 = NTMP(IMTL)	DAH 1380
DO 71 ITMP=1,NTMP1	DAH 1390
71 READ(ICRD,1002) IMPLL(IMTL,ITMP), (E(IMTL,J,ITMP),J=1,9)	DAH 1400
READ(ICRD,100) NTYEL, NELCH, (ITYEL(J),IXELCH(J),J=1,NELCH)	DAH 1410
CALL TITLE	DAH 1420
WRITE(IWRT,206)	DAH 1430
WRITE(IWRT,306) (IMATL(J), IXMLCH(J), J=1,NMLCH)	DAH 1440
I = 0	DAH 1450
97 CALL TITLE	DAH 1460
WRITE(IWRT,307)	DAH 1470
98 I = I+1	DAH 1480
IF(I .GT. NELCH) GO TO 99	DAH 1490
WRITE(IWRT,306) ITYEL(I), IXELCH(I)	DAH 1500
LINE = LINE + 1	DAH 1510
IF(LINE .LT. 48) GO TO 98	DAH 1520
GO TO 97	DAH 1530

99 CONTINUE	DAH 1540
ZELTHS = ZLNTH/NELZ	DAH 1550
NGNP = 136*(NELZ+1)	DAH 1560
NEL = 20*NELZ	DAH 1570
NELZ1 = NELZ + 1	DAH 1580
DO 46 J=1,24	DAH 1590
IX(1,J) = IXDT1(J)	DAH 1600
IX(2,J) = IXDT2(J)	DAH 1610
IX(3,J) = IXDT3(J)	DAH 1620
IX(4,J) = IXDT4(J)	DAH 1630
IX(5,J) = IXDT5(J)	DAH 1640
IX(6,J) = IXDT6(J)	DAH 1650
IX(7,J) = IXDT7(J)	DAH 1660
IX(8,J) = IXDT8(J)	DAH 1670
IX(9,J) = IXDT9(J)	DAH 1680
IX(10,J) = IXDT10(J)	DAH 1690
IX(11,J) = IXDT11(J)	DAH 1700
IX(12,J) = IXDT12(J)	DAH 1710
IX(13,J) = IXDT13(J)	DAH 1720
IX(14,J) = IXDT14(J)	DAH 1730
IX(15,J) = IXDT15(J)	DAH 1740
IX(16,J) = IXDT16(J)	DAH 1750
IX(17,J) = IXDT17(J)	DAH 1760
IX(18,J) = IXDT18(J)	DAH 1770
IX(19,J) = IXDT19(J)	DAH 1780
46 IX(20,J) = IXDT20(J)	DAH 1790
IF(NELZ.EQ. 1) GO TO 47	DAH 1800
DO 48 IELZ=2,NELZ	DAH 1810
DO 48 I=1,20	DAH 1820
M = 136*(IELZ-1)	DAH 1830
L = I+20*(IELZ-1)	DAH 1840
DO 48 J=1,24	DAH 1850
48 IX(I,J) = IX(I,J) + M	DAH 1860
47 CONTINUE	DAH 1870
IF(IFLHL.EQ. 0) GO TO 75	DAH 1880
DO 78 IELZ=1,NELZ	DAH 1890
IELZM1 = IELZ-1	DAH 1900
L = 136 * IELZM1	DAH 1910
DO 83 I=1,24	DAH 1920
IX(NEL+1,I) = IXDTP1(I) + L	DAH 1930
IX(NEL+2,I) = IXDTP2(I) + L	DAH 1940
IX(NEL+3,I) = IXDTP3(I) + L	DAH 1950
83 IX(NEL+4,I) = IXDTP4(I) + L	DAH 1960
L = 9 * IELZM1	DAH 1970
DO 84 I=1,10	DAH 1980
IX(NEL+1,IDX1(I)) = NGNP + IPLNP1(I) + L	DAH 1990
IX(NEL+2,IDX2(I)) = NGNP + IPLNP2(I) + L	DAH 2000
IX(NEL+3,IDX3(I)) = NGNP + IPLNP3(I) + L	DAH 2010
84 IX(NEL+4,IDX4(I)) = NGNP + IPLNP4(I) + L	DAH 2020
78 NEL = NEL + 4	DAH 2030
NGNP = NGNP + 9*(NELZ+1)	DAH 2040

75 CONTINUE	DAH 2050
IXELCH(NELCH+1) = 0	DAH 2060
IXMLCH(NMLCH+1) = 0	DAH 2070
I = 0	DAH 2080
J = 0	DAH 2090
DO 23 INEL=1,NEL	DAH 2100
IF(INEL .EQ. IXMLCH(I+1)) I=I+1	DAH 2110
IF(INEL .EQ. IXELCH(J+1)) J=J+1	DAH 2120
IX(INEL,25) = IMATL(I)	DAH 2130
IX(INEL,26) = IYEL(J)	DAH 2140
23 CONTINUE	DAH 2150
DO 33 I=1,NEL	DAH 2160
33 IX(I,27) = ICLASS	DAH 2170
DO 35 I=1,NGNP	DAH 2180
35 MTLND(I) = 0	DAH 2190
X(1) = RADHL	DAH 2200
DO 49 I=7,13	DAH 2210
49 X(I) = 0.00	DAH 2220
X(14) = (XINSRT-RADHL)/3.00+RADHL	DAH 2230
X(16) = XINSRT / 3.00	DAH 2240
X(17) = X(16)	DAH 2250
X(18) = 2.00 * (XINSRT-RADHL)/3.00+RADHL	DAH 2260
X(20) = 2.00 * X(16)	DAH 2270
X(21) = X(20)	DAH 2280
DO 50 I=22,28	DAH 2290
50 X(I) = XINSRT	DAH 2300
X(29) = (XLNTH-XINSRT) / 3.00 + XINSRT	DAH 2310
X(30) = X(29)	DAH 2320
X(31) = X(29)	DAH 2330
X(32) = 2.00*(XLNTH-XINSRT) / 3.00 + XINSRT	DAH 2340
X(33) = X(32)	DAH 2350
X(34) = X(32)	DAH 2360
DO 51 I=35,41	DAH 2370
51 X(I) = XLNTH	DAH 2380
Y(1) = 0.00	DAH 2390
Y(7)=RADHL	DAH 2400
Y(8) = (YINSRT-RADHL)/3.00+RADHL	DAH 2410
Y(9) = 2.00* (YINSRT-RADHL)/3.00+RADHL	DAH 2420
Y(10) = YINSRT	DAH 2430
Y(12) = 2.00 * (YLNTH-YINSRT)/3.00 + YINSRT	DAH 2440
Y(13) = YLNTH	DAH 2450
Y(14) = 0.00	DAH 2460
Y(11) = (YLNTH-YINSRT)/3.00 + YINSRT	DAH 2470
Y(16) = YINSRT	DAH 2480
Y(17) = YLNTH	DAH 2490
Y(18) = 0.00	DAH 2500
Y(20) = YINSRT	DAH 2510
Y(21) = YLNTH	DAH 2520
Y(22) = 0.00	DAH 2530
Y(23) = YINSRT / 3.00	DAH 2540
Y(24) = YINSRT / 3.00 * 2.00	DAH 2550

Y(25) = YINSRT	DAH 2560
Y(26) = Y(11)	DAH 2570
Y(27) = Y(12)	DAH 2580
Y(28) = YLNTH	DAH 2590
Y(29) = 0.00	DAH 2600
Y(30) = YINSRT	DAH 2610
Y(31) = YLNTH	DAH 2620
Y(32) = 0.00	DAH 2630
Y(33) = YINSRT	DAH 2640
Y(34) = YLNTH	DAH 2650
DO 52 I=35,41	DAH 2660
52 Y(I) = Y(I-13)	DAH 2670
IF (IFLHL .EQ. 0) GO TO 79	DAH 2680
NGNPI = 136*(NELZ+1)	DAH 2690
NEL1 = 20*NELZ	DAH 2700
DO 60 IELZ=1,NELZ1	DAH 2710
M = NGNPI + (IELZ-1)*9	DAH 2720
X(M+1) = -2.00*RADHL/3.00	DAH 2730
X(M+2) = -RADHL/3.00	DAH 2740
X(M+3) = 0.00	DAH 2750
X(M+4) = -X(M+2)	DAH 2760
X(M+5) = -X(M+1)	DAH 2770
X(M+6) = 0.00	DAH 2780
X(M+7) = 0.00	DAH 2790
X(M+8) = 0.00	DAH 2800
X(M+9) = 0.00	DAH 2810
DO 86 I=1,5	DAH 2820
86 Y(M+1) = 0.00	DAH 2830
Y(M+6) = X(M+5)	DAH 2840
Y(M+7) = X(M+4)	DAH 2850
Y(M+8) = X(M+2)	DAH 2860
Y(M+9) = X(M+1)	DAH 2870
DO 80 I=1,9	DAH 2880
80 Z(I+M) = (IELZ-1) * ZELTHS	DAH 2890
79 CONTINUE	DAH 2900
GO TO (1,2,3), ITYHL	DAH 2910
1 SXTHPI = 3.141592613569800 / 12.00	DAH 2920
X(2) = RADHL * DCOS(1.00*SXTHPI)	DAH 2930
X(3) = RADHL * DCOS(2.00*SXTHPI)	DAH 2940
X(4) = RADHL * DCOS(3.00*SXTHPI)	DAH 2950
X(5) = RADHL * DCOS(4.00*SXTHPI)	DAH 2960
X(6) = RADHL * DCOS(5.00*SXTHPI)	DAH 2970
X(15) = (XINSRT-RADHL*DCOS(3.00*SXTHPI))/3.00	DAH 2980
1 + RADHL*DCOS(3.00*SXTHPI)	DAH 2990
X(19) = 2.00*(XINSRT-RADHL*DCOS(3.00*SXTHPI))/3.00	DAH 3000
1 + RADHL*DCOS(3.00*SXTHPI)	DAH 3010
Y(2) = RADHL*DSIN(1.00*SXTHPI)	DAH 3020
Y(3) = RADHL*DSIN(2.00*SXTHPI)	DAH 3030
Y(4) = RADHL*DSIN(3.00*SXTHPI)	DAH 3040
Y(5) = RADHL*DSIN(4.00*SXTHPI)	DAH 3050
Y(6) = RADHL*DSIN(5.00*SXTHPI)	DAH 3060

Y(15) = (YINSRT-RADHL*DSIN(3.00*SXTHPI)) / 3.00	DAH 3070
1 + RADHL * DSIN(3.00*SXTHPI)	DAH 3080
Y(19) = 2.00*(YINSRT-RADHL*DSIN(3.00*SXTHPI)) / 3.00	DAH 3090
1 + RADHL * DSIN(3.00*SXTHPI)	DAH 3100
GO TO 7	DAH 3110
2 DO 87 I=2,4	DAH 3120
X(I) = RADHL	DAH 3130
87 Y(I+2) = RADHL	DAH 3140
X(5) = 2.00 * RADHL/3.00	DAH 3150
X(6) = RADHL/3.00	DAH 3160
Y(2) = X(6)	DAH 3170
Y(3) = X(5)	DAH 3180
X(15) = X(14)	DAH 3190
X(19) = X(18)	DAH 3200
Y(15) = Y(8)	DAH 3210
Y(19) = Y(9)	DAH 3220
GO TO 7	DAH 3230
3 X(2) = 5.00 * RADHL/6.00	DAH 3240
X(3) = 2.00 * RADHL/3.00	DAH 3250
X(4) = RADHL/2.00	DAH 3260
X(5) = X(3) / 2.00	DAH 3270
X(6) = X(5) / 2.00	DAH 3280
DO 88 I=2,6	DAH 3290
88 Y(I) = X(8-I)	DAH 3300
X(15) = (X(14) + X(16))/2.00	DAH 3310
X(19) = (X(18) + X(20))/2.00	DAH 3320
Y(15) = (Y(8) + Y(23))/2.00	DAH 3330
Y(19) = (Y(9) + Y(24))/2.00	DAH 3340
7 CONTINUE	DAH 3350
DO 601 I=1,6	DAH 3360
X(41+I) = -X(I)	DAH 3370
601 Y(41+I) = Y(I)	DAH 3380
DO 602 I=14,41	DAH 3390
X(34+I) = -X(I)	DAH 3400
602 Y(34+I) = Y(I)	DAH 3410
DO 603 I=2,13	DAH 3420
X(74+I) = -X(I)	DAH 3430
603 Y(74+I) = -Y(I)	DAH 3440
DO 604 I=15,17	DAH 3450
X(73+I) = -X(I)	DAH 3460
604 Y(73+I) = -Y(I)	DAH 3470
DO 605 I=19,21	DAH 3480
X(72+I) = -X(I)	DAH 3490
605 Y(72+I) = -Y(I)	DAH 3500
DO 606 I=23,28	DAH 3510
X(71+I) = -X(I)	DAH 3520
606 Y(71+I) = -Y(I)	DAH 3530
X(100) = -X(30)	DAH 3540
X(101) = -X(31)	DAH 3550
X(102) = -X(33)	DAH 3560
X(103) = -X(34)	DAH 3570

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Y(100) = -Y(30)
Y(101) = -Y(31)
Y(102) = -Y(33)
Y(103) = -Y(34)
DO 607 I=36,41
X(68+I) = -X(I)
607 Y(68+I) = -Y(I)
DO 608 I=2,6
X(108+I) = X(I)
608 Y(108+I) = -Y(I)
DO 609 I=88,109
X(27+I) = -X(I)
609 Y(27+I) = Y(I)
DO 53 I=1,136
53 Z(I) = C.DG
DO 54 IELZ=1,NELZ
XL = IELZ * ZELTHS
DO 54 I=1,136
L = IELZ * 136 + I
Z(L) = XL
Y(L) = Y(I)
54 X(L) = X(I)
DO 55 I=1,NGNP
ICUOE(I) = 0
UX(I)=0.00
UY(I)=0.00
55 UZ(I)=0.00
DO 58 I=1,136
58 ICUOE(I) = 5
L = 136*(NELZ+1)
DO 57 I=1,9
57 ICUOE(I+L) = 5
IF(LDMD.EQ. 1) GO TO 60
DO 56 I=36,41
ICUOE(I) = 3
ICUOE(I+34) = 3
ICUOE(I+68) = 3
ICUOE(I+95) = 3
UX(I) = DSPLD
UX(I+95) = DSPLD
UX(I+68) = -DSPLD
UX(I+34) = -DSPLD
DO 56 IELZ=1,NELZ
L = 136 * IELZ
ICUOE(I+L) = 1
ICUOE(I+L+34) = 1
ICUOE(I+L+68) = 1
ICUOE(I+L+95) = 1
UX(I+L) = DSPLD
UX(I+L+95) = DSPLD
UX(I+L+34) = -DSPLD

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DAH 3580
DAH 3590
DAH 3600
DAH 3610
DAH 3620
DAH 3630
DAH 3640
DAH 3650
DAH 3660
DAH 3670
DAH 3680
DAH 3690
DAH 3700
DAH 3710
DAH 3720
DAH 3730
DAH 3740
DAH 3750
DAH 3760
DAH 3770
DAH 3780
DAH 3790
DAH 3800
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DAH 3890
DAH 3900
DAH 3910
DAH 3920
DAH 3930
DAH 3940
DAH 3950
DAH 3960
DAH 3970
DAH 3980
DAH 3990
DAH 4000
DAH 4010
DAH 4020
DAH 4030
DAH 4040
DAH 4050
DAH 4060
DAH 4070
DAH 4080

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56 UX(I+L+68) = -DSPLD	DAH 4090
ICODE(35) = 7	DAH 4100
ICODE(69) = 7	DAH 4110
UX(35) = DSPLD	DAH 4120
UX(69) = -DSPLD	DAH 4130
DO 63 IELZ=1,NELZ	DAH 4140
L = 136*IELZ	DAH 4150
ICODE(35+L) = 1	DAH 4160
ICODE(69+L) = 1	DAH 4170
UX(35+L) = DSPLD	DAH 4180
63 UX(69+L) = -DSPLD	DAH 4190
GO TO 9	DAH 4200
60 CONTINUE	DAH 4210
IF(NELZ .EQ. 1) GO TO 65	DAH 4220
DO 64 IELZ=2,NELZ	DAH 4230
M = 136*(IELZ-1)	DAH 4240
DO 72 I=35,38	DAH 4250
72 UX(I+M) = XLDSQ(I-34) * YINSRT*ZELTHS * DSPLD/8.00	DAH 4260
DO 73 I=38,41	DAH 4270
73 UX(I+M) = UX(I+M) + (XLDSQ(I-37) * (YLNTH-YINSRT)*ZELTHS	DAH 4280
1 *DSPLD/8.00)	DAH 4290
64 CONTINUE	DAH 4300
65 DO 66 I=35,38	DAH 4310
UX(I) = XLDSQ(I-34) * YINSRT*ZELTHS * DSPLD/16.00	DAH 4320
M = 1+136*NELZ	DAH 4330
66 UX(M) = XLDSQ(I-34) * YINSRT*ZELTHS * DSPLD/16.00	DAH 4340
DO 74 I=38,41	DAH 4350
M = 1+136*NELZ	DAH 4360
UX(M) = UX(M) + (XLDSQ(I-37) * (YLNTH-YINSRT)*ZELTHS	DAH 4370
1 *DSPLD/16.00)	DAH 4380
74 UX(I) = UX(I) + (XLDSQ(I-37) * (YLNTH-YINSRT)*ZELTHS	DAH 4390
1 *DSPLD/16.00)	DAH 4400
NELZP1 = NELZ+1	DAH 4410
DO 81 I=36,41	DAH 4420
DO 81 IELZ=1,NELZP1	DAH 4430
M = 136 * (IELZ-1) + 1	DAH 4440
UX(M+34) = -UX(I)	DAH 4450
UX(M+68) = -UX(I)	DAH 4460
81 UX(M+95) = UX(I)	DAH 4470
DO 82 I=1,NELZP1	DAH 4480
M = 136*(I-1)	DAH 4490
UX(M+35) = 2.00 * UX(M+35)	DAH 4500
82 UX(M+69) = -UX(M+35)	DAH 4510
ICODE(35) = 6	DAH 4520
ICODE(69) = 6	DAH 4530
ICODE(13) = 3	DAH 4540
ICODE(87) = 3	DAH 4550
9 RETURN	DAH 4560
END	DAH 4570

	SUBROUTINE TITLE	TIH	10
C		TIH	20
C	*****	TIH	30
C	*	TIH	40
C	* SUBROUTINE TITLE PRINTS THE HEADING ON EACH PAGE	TIH	50
C	*	TIH	60
C	*****	TIH	70
C		TIH	80
	IMPLICIT REAL*8 (A-H,O-Z)	TIH	90
	COMMON / HEAD / HED(10),ICRD,IWRT,IPAGE,LINE	TIH	100
100	FORMAT (1H1,'FEM 72-DOF GENERAL HEXAHEDRONS THERMO-ELASTIC, VARYINTI	TIH	110
	IG MATERIAL PROPERTIES, DANA', 9X, 'PAGE', I3)	TIH	120
101	FORMAT (1H0,10A8)	TIH	130
	WRITE (IWRT,100) IPAGE	TIH	140
	WRITE (IWRT,101) HED	TIH	150
	IPAGE= IPAGE +1	TIH	160
	LINE = 0	TIH	170
	RETURN	TIH	180
	END	TIH	190

